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ENHANCED BIOLOGICAL ATTENUATION OF AIRCRAFT DEICING FLUID RUNOFF USING CONSTRUCTED WETLANDS

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14. ABSTRACT
The Naval Facilities Engineering Service Center partnered with Wetland Solutions Inc., Anteon Inc., University of Western Washington and University of Colorado have demonstrated the ability of a constructed subsurface flow (SSF) treatment wetland to reduce the negative environmental effects of aircraft deicing operations. The field-scale, 0.6 acre SSF wetland was designed to treat runoff from the application of aircraft deicing fluid (ADF) at Westover Air Reserve Base in Springfield, Massachusetts. While exact chemical composition of ADFs are proprietary, ADF consists of approximately 80 percent propylene or ethylene glycol, 18 percent water, and 2 percent of additives for improved functionality. Environmental impacts of ADF usage are the potential of high five-day biochemical oxygen demand (BOD) and low dissolved oxygen (DO) in receiving waters. Extreme conditions could create eutrophication, algal blooms, acute fish die-off, and ecological risks from both low DO and toxic additives in the ADF. The SSF wetland demonstrated the ability to reduce ADF discharge concentrations by 80 percent. The technology is safe for use at air facilities because it does not produce a desirable bird habitat since all flow is below ground surface.

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FINAL REPORT

Environmental Security Technology Certification Program

ENHANCED BIOLOGICAL ATTENUATION OF AIRCRAFT DEICING FLUID RUNOFF USING CONSTRUCTED WETLANDS

January 2004

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List of Acronyms

ADF	Aircraft Deicing and/or Anti-icing Fluids
AFRC	Air Force Reserve Command
AFRES	Air Force Reserve
ARB	Air Reserve Base
AW	Airlift Wing
BASH	Bird and Animal Strike Hazard
BMP	Best Management Practices
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
CTW	Constructed Treatment Wetland
DoD	Department of Defense
FOTW	Federally Owned Treatment Works
HLR	Hydraulic Loading Rate
HRT	Hydraulic Residence Time
MAW	Military Airlift Wing
NOV	Notice of Violation
NPDES	National Pollutant Discharge Elimination System
OWin	Oil/Water Separator Inflow
POTW	Public Owned Treatment Works
SF	Surface Flow Wetlands
SSF	Subsurface Flow
TC	Total Carbon
TOC	Total Organic Carbon
TSS	Total Suspended Solids
UC	University of Colorado
VOC	Volatile Organic Compounds
Win	Wetland Inflow
Wout	Wetland Outflow
WWU	Western Washington University

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Abstract

During winter months at Department of Defense (DoD) air bases, large amounts of aircraft deicing and anti-icing fluids (ADFs) (primarily propylene glycol and ethylene glycol and various additives) are used to ensure flight safety during certain adverse weather conditions. Standard practices at both military air bases and private airports are to direct deicing effluent to large stabilization ponds, the sanitary storm sewer, to vegetated swales, or directly to the environment.

An issue with high use of ADFs is the potential of high five-day biochemical oxygen demand (BOD) and low dissolved oxygen (DO) in receiving waters. Extreme conditions could create eutrophication, algal blooms, acute fish die-off, and ecological risks. Discharge to the local public owned treatment works (POTW) or base (federally owned) treatment works (FOTW) is an alternative at some locations. However, the feasibility of this method needs to be determined on a site-specific basis for several reasons, including POTW design capacity, cost, logistics and regulations.

Constructed wetlands have a history of use for treating polluted waters dating back to the early 1950s. In many instances, constructed treatment wetlands can provide a cost-effective alternative to conventional treatment in a mechanical wastewater treatment facility. The use of constructed wetlands for treatment of ADFs is one possible method of resolving the problems described above. However, constructed wetlands have been applied to ADF treatment at only a few locations worldwide, and this application of wetland treatment technology is still innovative since it has not been applied on a large or full scale.

A 0.6-acre horizontal subsurface flow (SSF) constructed treatment wetland (CTW) system was installed at the Westover Air Reserve Base (ARB) in Massachusetts to demonstrate the efficacy of this innovative technology in treating the ADF from on-site deicing operations. A SSF CTW was selected for this demonstration because it is insulated from cold temperatures, efficient (higher surface area for microbial attachment), unlikely to have ecological risks, and is free from bird air-strike hazard since there is no standing water.

The CTW demonstration project monitored the performance of the SSF CTW for a single winter season (2002–2003) of deicing at the Westover ARB. The CTW was less than one year old at the end of this demonstration. Deicing activity during the demonstration period was unusually great (about 5 times the average) and the SSF CTW was still able to meet the goals set for the project.

During the project the permit for the outfall had changed from an individual to a multi-sector permit. The objectives for effluent toxicity and non-point-source (NPS) removal were not assessed because higher than expected construction costs necessitated a reduction in project analytical costs. This change made the performance objective of compliance with the original individual NPDES inapplicable. For the primary performance criteria of cost reduction, mission impacts (or readiness), and land use, the wetland system achieved the performance criteria. The system is estimated to cost $3,000 to operate and maintain annually, which is only $500 more than expected.

The wetland system demonstrated its ability to achieve significant BOD slug load reductions. BOD mass removal rates at greater than 220 kg/ha/d were higher than more than 97 percent of all of the annual average operational data values (N = 191) in the North American Treatment Wetland Database (version 2) [1]. The apparent wetland background or minimum achievable BOD concentration during a deicing event was relatively high at about 133 mg/L. Peak inflow BOD concentrations ranged from 974 to 15,098 mg/L during 10 deicing events in 2002 and these were reduced by more than 50 percent in 5 of the 10 events. It is likely that BOD removal rates would have been higher in a fully matured and developed SSF CTW.

The performance of this system can reasonably be expected to increase for the next several years and achieve a higher level than was measured during this first year of operation. The wetland plant community should approach full coverage by the end of the 2003 growing season and performance during the upcoming winter of 2003 – 2004 will reflect the effect of that increased coverage.

Due to the increased deicing activity during the demonstration period and the associated high loadings, the site area constraint was the major limitation for the project. The available area for the CTW was too small for the amount of flow and ADF application

from the watershed in 2002-2003. It is estimated that at least 2 to 2.5 acres of CTW would be required to fully treat the ADF discharging to Cooley Brook at Outfall 001 during normal and extreme deicing years.

The costs associated with discharging ADF wastes to a full-scale SSF CTW were compared to the estimated cost of discharge to a local POTW. POTW discharge was selected for cost comparison since it is considered the ‘default’ treatment methodology for small- to medium-sized airports and military air facilities. These costs were evaluated for an average annual ADF usage of about 10,000 gallons. The life-cycle basis was a 20-year project life at a 6 percent discount rate. Actual usage in 2002-2003 during the CTW Demonstration Project was higher than average with over 50,000 gallons. Annualized cost estimates were $26,940 for the existing 0.6 acre CTW, $71,394 for a full-scale CTW at this site (2 acres), and $105,182 for transfer of the glycol-containing stormwater to a POTW for treatment and disposal. The CTW technology is estimated to be about 32 percent less costly on an annual basis ($7.14 vs. $10.52 per gallon of ADF) than the most likely alternative technology, which is discharge to the local POTW. Further, the treatment wetland would be much less costly compared to other available alternatives such as a fixed-film bioreactor. A bioreactor would have higher capital and operating costs.

Cost savings will be less if a facility has been discharging to the POTW and now chooses to install a full-scale CTW. This is because capital costs have already been expended for the POTW discharge and not for the CTW. The savings in annual costs with a CTW is $76,000 per year. The payback period for this scenario is 10.5 years.

1. Introduction

1.1 Background

1.1.1 Overview of the Problem

During winter months at Department of Defense (DoD) air bases, large amounts of aircraft deicing and anti-icing fluids (ADF) (primarily propylene glycol and ethylene glycol and various additives) are used to ensure flight safety during certain adverse weather conditions. A portion of these ADFs are released to the environment with inadequate treatment due to several constraints including a lack of technically feasible and cost effective tools for collection and treatment. By proximity, many DoD installations discharge aircraft deicing runoff to bays, lakes, rivers, streams, and other natural waterbodies. Some of these waterbodies are very sensitive or have special designation warranting increased protection. Also, some activities release deicing runoff directly to the ground, contaminating soils and jeopardizing groundwater supplies [2,3].

Based on FY96 purchase records from the National Stock System, the DoD had to treat, dispose, or otherwise handle an estimated 15 million gallons of propylene glycol deicing fluid runoff. Once used for their intended purpose, the ADF become an environmental liability because of their toxicity [4,5,6], their high biochemical oxygen demand (BOD) loading on receiving waters [7,8], and have a propensity to severely disturb receiving biological systems.

A recently completed study of Air Force aircraft deicing activities reports the liability of non-compliance. A base in Missouri has been issued a notice of violation (NOV) as the result of a fish kill and another in Arkansas may have a pending NOV because of an exceedance of the chemical oxygen demand (COD) limits. Both instances are a direct result of deicing activities [9]. From a legal perspective, both Chicago's O'Hare airport and Baltimore-Washington International airport have received notices of intent to sue by separate environmental coalitions [10].

Standard practices at both military air bases and private airports are to direct untreated deicing effluent to large stabilization ponds, the sanitary or storm sewer, to vegetated swales, or directly to the environment. Most of these systems do not respond well to BOD shock-loads. Stabilization ponds or lagoons (not to be confused with wetlands) require large land areas, may increase the risk of bird air strikes, and can not meet secondary treatment standards by themselves[1]. Untreated discharges to the storm sewer or environment are unacceptable because ADF releases can lead to eutrophication, algal blooms, acute fish die-off from low dissolved oxygen levels, increased ecological risks, and soil and groundwater contamination.

Discharge to the local public owned treatment works (POTW) or base federally owned treatment works (FOTW) works at some locations. However, the feasibility of this

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[1] No secondary standards for BMPs. Only CWA § 402 stormwater requirements which have no effluent limitations (numerical)

method needs to be determined on a site-specific basis for several reasons including cost, logistics, and capacity. Disposal to the sanitary sewer is not an option for bases where the municipal wastewater plant is at or near flow capacity, cannot assimilate the high BOD loadings, or is otherwise unable or unwilling to accept the effluent.

An indication of POTW treatability limitations was experienced at Salt Lake City's Wastewater Reclamation Plant. During the two winters following a 1991 agreement to receive deicing runoff from the Salt Lake City International Airport, the plant experienced five failures of its trickling filter/solids contact process and five permit exceedances [12.] Because of this, (and added costs) on-site storage and metering of effluent into the sanitary sewer is generally required to prevent the high loadings from causing treatment plant upsets.

1.1.2 Constructed Treatment Wetland Technology

Constructed wetlands have a history of use for treating polluted waters dating back to the early 1950s. The use of constructed wetlands for treatment of ADF is an innovative method of resolving the problem described above. However constructed wetlands have been applied to ADF treatment at only a few locations worldwide and this application of the wetland treatment technology is still innovative since it has not been applied on a large or full scale.

There are two major categories of constructed wetlands treatment [13]: surface flow (SF) and subsurface flow (SSF). In SF treatment wetlands water flows over the ground surface in a relatively shallow sheetflow similar to a natural wetland marsh. In a SSF treatment wetland water flows horizontally or vertically in the subsurface through a porous medium such as coarse sand or gravel. There should be no surface water in a properly designed and operated SSF wetland.

Treatment wetlands have been built at thousands of locations throughout the U.S. and the world [13,14]. They have been found to be a cost effective technology for treating a variety of municipal, industrial, and non-point source wastewaters and a large array of pollutants including BOD, COD, nutrients, and trace metals and organics. This is important for deicing treatment since the runoff is likely to contain additional urban pollutants such as heavy metals and nutrients. Constructed wetlands are being applied to treat highway runoff, which is similar in composition to airfield runoff in terms of BOD, suspended solids, heavy metals, hydrocarbons, deicing salts, particulate pollution originating from road and vehicle wear, and fecal coliforms.

A 0.6-acre horizontal SSF constructed treatment wetland (CTW) system was installed at the Westover Air Reserve Base (ARB) in Massachusetts to demonstrate the efficacy of this innovative technology in treating the ADF from on-site deicing operations. It is still in operation. A SSF CTW was selected because it has several advantages over SF systems in this application. A SSF system is better insulated from cold temperatures, more efficient (higher surface area for microbial attachment), less likely to have significant ecological risks, and not an added bird-air strike hazard (BASH) since there is no standing water[13,15.] Figure 1-1 illustrates the major features of a typical SSF CTW.

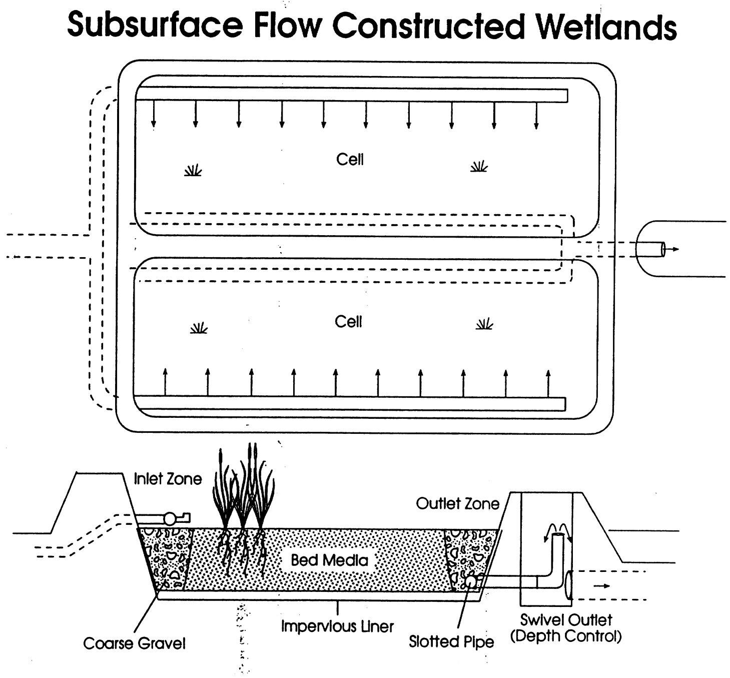


Figure 1-1. Subsurface Flow Constructed Treatment Wetland Typical Plan and Profile [13].

The application of the SSF CWT technology for enhanced biodegradation of glycol-based deicing compounds has been sufficiently developed for demonstration at the field-scale. Pilot field testing of biological and CWT systems strongly suggest the technology can effectively treat deicing runoff [8,16,17]. The latest data from a pilot scale SSF CWT study at London's Heathrow airport show an average removal efficiency of 78 percent; a stable and shock-load resistant populations of glycol-respiring microbes (10^{-5} – 10^{-7} colony forming units (CFU)/g substrate dry weight). The Heathrow CWT pilot system removal efficiency has steadily improved as the treatment bed has matured [8].

Further, laboratory data that shows bio-utilization of glycols by hundreds of microbial cultures, by the number of full-scale, constructed wetlands successfully operating in cold climates[18,19,20,21] and by recently published data from Heathrow Airport's pilot-scale constructed wetland systems [8].

1.1.3 Expected Benefits of the Demonstration Project

Conventional practices and alternatives for ADF wastewater management include the following:

- Collection and recycle/reuse
- Collection and treatment at a POTW
- Detention with partial treatment
- No treatment with release to the environment

All of these options are costly in terms of economic and/or environmental impacts. Additional cost-effective and environmentally friendly options for ADF management are

needed. If the use of SSF CTW is demonstrated to be an effective waste management tool for ADF, then water quality protection will become a more realistic goal for DoD installations that currently do not have adequate management measures for this environmental pollutant.

1.2 Objectives of the Demonstration

1.2.1 Technology Validation

The objective of the CTW Technology Demonstration Project was to demonstrate that SSF constructed treatment wetland technology could cost-effectively remove harmful chemicals from deicing wastestreams for immediate and long-term compliance with water quality regulations. By constructing and monitoring a field-scale SSF treatment wetland system, this project illustrated the efficacy of the CTW technology for enhanced biological treatment of deicing effluent and runoff at DoD air bases.

1.2.2 Key Pollutants of Concern

The key pollutant of concern for this project is ADF. ADFs have very high biochemical oxygen demand potential and pollute receiving waters by exerting this potential oxygen demand through promotion of rapid growth of heterotrophic microbial populations. This high oxygen demand depletes available dissolved oxygen in the receiving water and impacts or alters natural populations of flora and fauna including primary producers such as algae, macroinvertebrate populations, and fish.

In addition to the gross effect of oxygen depletion, most ADF include manufacturer additives that may have additional environmental effects. Of particular interest are triazoles (man-made aromatic compounds) which, at high concentrations, are known to be carcinogenic and acutely toxic to indigenous aquatic fauna.

1.2.3 Location of the Demonstration Project

The SSF Constructed Treatment Wetland ADF Attenuation Technology Demonstration Project (CTW Technology Demonstration Project) is located at Westover ARB near Springfield, Massachusetts (Figure 1-2). Westover ARB deices aircraft at multiple locations, including each end of their primary runway. The focus of this project is primarily on deicing operations on the East ramp (Figure 1-3). The East ramp is used for primary deicing operations when general deicing is required. However, under certain conditions pilots will require deicing at the end of each runway. This is sometimes necessary to prevent ice formation from the time of first deicing until take-off.

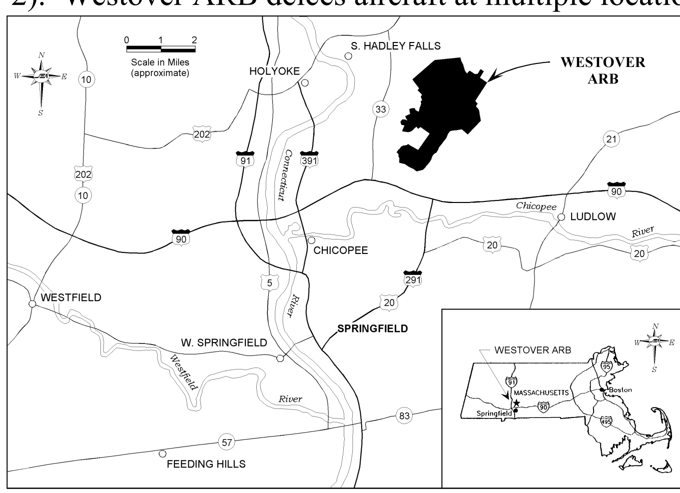


Figure 1-2. Westover ARB and Surrounding Region

Runoff from each deicing location is ultimately released to the environment. Runoff from the East ramp is routed to Outfall 001 through an oil/water (O/W) separator. Runoff from the North end drains into an adjacent *natural* wetland. The runoff from the opposite end drains to the surrounding grassy areas and ultimately to the groundwater. The fate, transport, and attenuation of glycols in this wetland are being studied by the University of Colorado, Boulder [22]. Also, Westover has applicable monitoring data that will help leverage project efforts at this location.

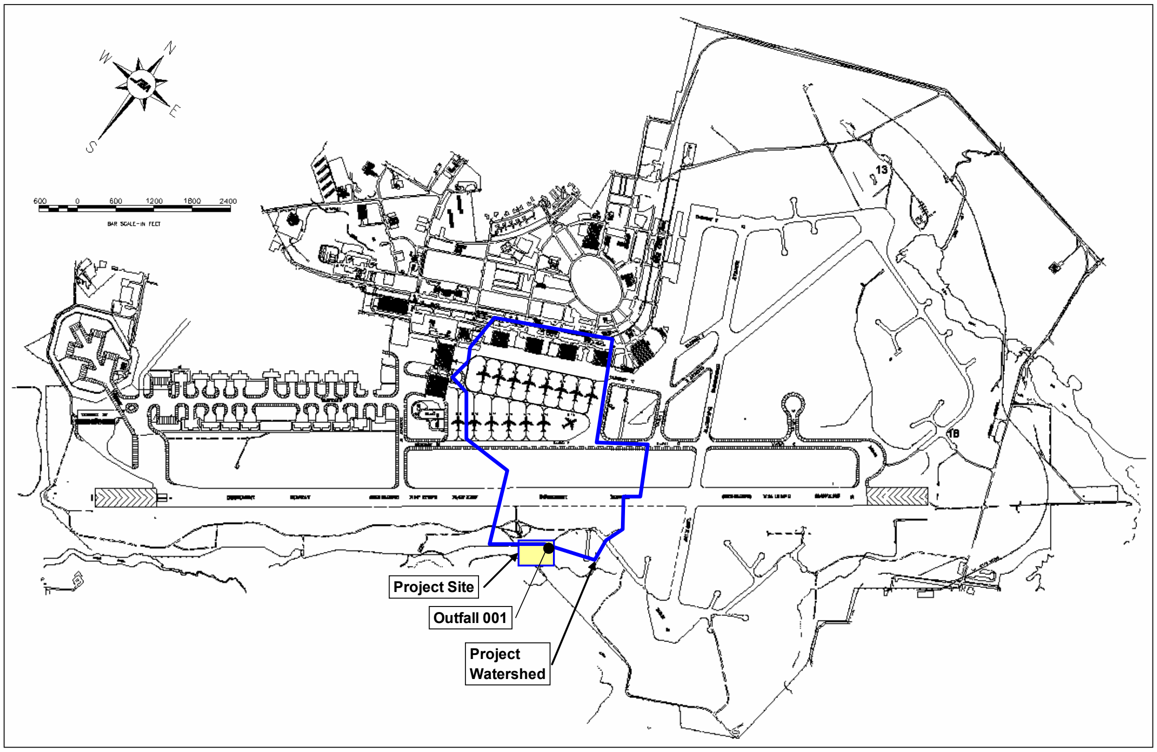


Figure 1-3. SSF CTW Technology Demonstration Project Watershed, Westover ARB

1.2.4 Potential Advantages of the Technology

The CTW Technology Demonstration Project was conducted to illustrate a number of important potential benefits for the DoD. These include the following:

- demonstration of an effective technology for ADF wastewater attenuation appropriate at some DoD air bases,
- cost-effective and low maintenance degradation of ADF with a natural treatment technology,
- synergism with on-going, Air Force funded research related to ADF degradation and treatment in conventional treatment systems, and
- conservation of fossil fuel energies consumed by conventional treatment technologies.

In addition to these potential DoD-wide improvements in ADF management, the CWT Technology Demonstration Project is the first control for the attenuation of ADF that finds its

way to storm sewers at the Westover ARB. Although this project was limited by funding and was not sized to provide complete attenuation of ADF impacts at the Outfall 001, it was successful at reducing peak pollutant concentrations and loads reaching Cooley Brook.

1.3 Regulatory Drivers

A variety of federal regulations may apply to the use, treatment, and disposal of ADFs at DoD facilities. The laws, regulations, and permit requirements applicable to aircraft deicing operations depend upon the actual use and specific site location. In addition to the federal regulations, there may be state, local and regional requirements or initiatives that also apply to the management of ADFs. Key drivers for the CTW Technology Demonstration project were enhanced compliance with the requirements of the Clean Water Act (CWA) and a good faith effort to comply with DoD ADF guidelines.

1.3.1 Clean Water Act

The CWA regulates all discharges of pollutants into Waters of the United States (Waters). Discharge of ADF-containing stormwaters is a point discharge to Waters. Point source discharges are covered by the National Pollutant Discharge Elimination System (NPDES) or Section 402 of the CWA. The NPDES Program requires a permit for all discharges into regulated waters. Section 402 is administered solely by the U.S. EPA or delegated to the appropriate state agency.

Constructed wetlands that are controlling pollutants in stormwater or from non-point sources into regulated waters must be converted by an NPDES permit. The permit will be an individual, general, or multi-sector permit. In the case of Westover ARB it is a multi-sector permit. It is anticipated that some bases will be impacted by the TMDL for BOD as in the case of Portland International Airport.

1.3.2 DoD Mandates

There are no specific DoD mandates for ADF release and environmental compliance.

1.4.1 Stakeholder/End-User Issues

DoD facilities that utilize aircraft deicing and ADFs are the primary stakeholders and end-users for the SSF CTW technology demonstrated by this project. However, CTWs have been used for stormwater and ADF management at only a few airports worldwide and at no DoD facilities prior to the current project. Results from this project and from continuing use of the existing CTW system at the Westover ARB will be a primary factor for consideration of this approach at other DoD facilities with similar ADF issues.

Potential barriers to future implementation of the CTW ADF management technology include the following:

- Lack of storage and pretreatment prior to CTW
- The potential large size of a full-scale facility that can fully attenuate all peak loads of ADF to achieve total compliance with requirements of the CWA

- Inadequate operational history and data collection at the Westover ARB CTW Technology Demonstration project to fully assess the long-term potential of the wetland once it has fully matured
- Inadequate dissemination of information about the advantages of the using the CTW technology at the Westover ARB

The first barrier can be partially lowered by increasing pretreatment and storage prior to treatment in a constructed wetland. The second potential barrier to implementation can be overcome by funding additional monitoring of the CTW Technology Demonstration Project through several years of maturation and under a variety of loading conditions. The third potential barrier can be overcome by effectively publishing the results of this project.

2. Technology Description

This section provides an introduction to the fundamental aspects of CTW function and application for management of ADFs. Design approaches are briefly described and their practical or potential applications toward solving environmental issues are addressed, as are their constraints and limitations. With over 10,000 full-scale constructed wetlands in operation worldwide [14], there are ample data to provide a practical application of the technology for pollution control. However, the CTW technology has not been widely applied to the management and treatment of ADFs. This section also describes the expected performance of CTWs for this insufficiently-studied application.

2.1 Technology Development and Application

2.1.1 Background and Applications

With respect to treatment of ADF-containing stormwaters, CTWs consistently perform the following beneficial treatment processes:

- Degradation of dissolved organic matter through microbial growth and respiration;
- Transformation and metabolism of toxic organic compounds; and
- Degradation and mass reductions of other stormwater contaminants including oils and grease, suspended solids, and nutrients.

CTW design necessitates an understanding of the fundamental mechanisms of wetland function, and hence, treatment. Because of their general effectiveness and adaptability for a wide range of pollutants, CTWs are used to improve the quality of such diverse point and non-point sources as domestic wastewaters, agricultural wastewaters, coal mine drainage, petroleum refinery wastewaters, landfill leachate, and pretreated industrial wastewater [13,14].

2.1.2 Constructed Wetland Types and Designs

Constructed wetlands have been intentionally used for water quality improvement since the 1950s [13]. Research on CTW design and performance really accelerated in the 1970s in response to the CWA and the technology matured and reached a fairly widespread application by the 1990s.

The two main types of CTWs that are presently in use include surface flow (SF) and subsurface flow (SSF) systems and are illustrated in Figure 2-1. SF systems outnumber SSF systems in the United States by over two to one [13,23]. However, in Europe SSF wetlands outnumber SF wetlands by a large margin [14]. In Europe many small treatment wetlands have been implemented for treatment of residential wastewater. SSF wetlands are advantageous in this application mainly because of the limited exposure pathway for direct human or wildlife contact with partially treated wastewaters. SSF wetlands hold promise for treatment of

industrial effluents or other wastewaters containing hazardous contaminants because of this inherent exposure-limiting characteristic of having the water flow below ground. SF wetlands, however, are much easier to design and build and are less costly to construct than SSF wetlands.

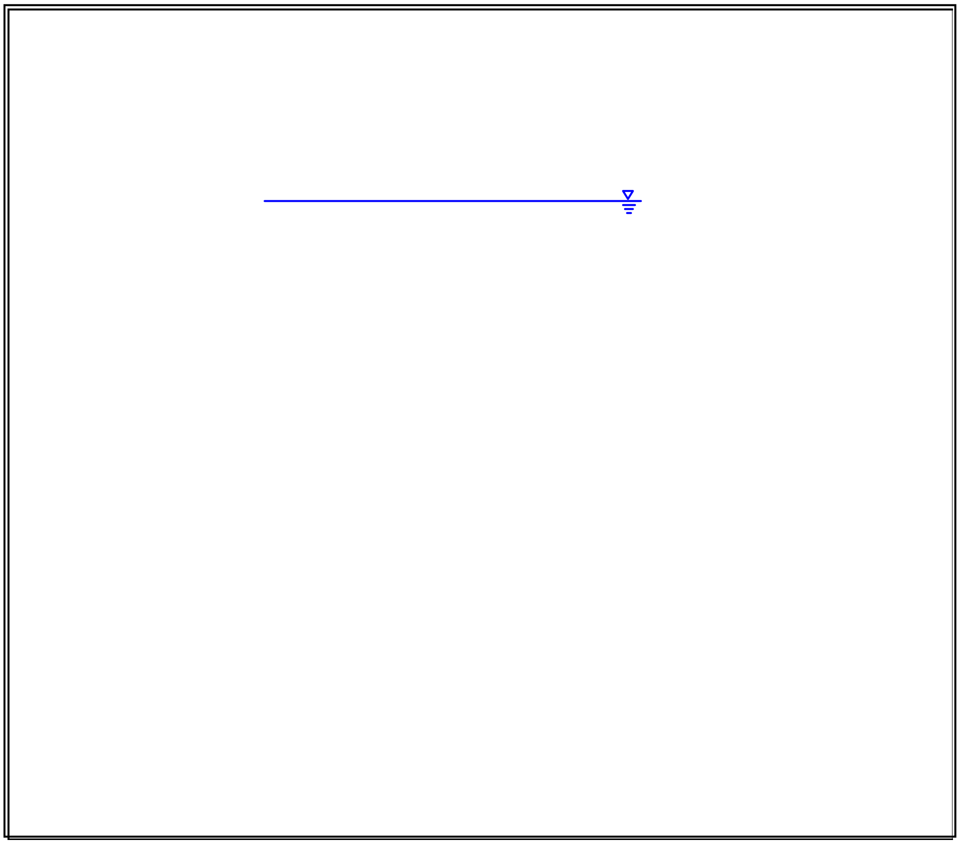


Figure 2-1: Types of Constructed Treatment Wetlands.

2.1.2.1 Surface Flow (SF) Constructed Treatment Wetlands

SF constructed wetlands consist of shallow earthen basins. Water to be treated is generally introduced at one end of the basin, flows through an area of rooted wetland plants, and is collected and discharged at the opposite end of the basin. The water surface remains above the substrate (usually soil) and moves through the wetland at relatively low velocities. Plants in these systems are able to withstand continuously saturated soil conditions and the resulting anaerobic soil conditions. Surface flow treatment wetlands have variable water column oxygen levels depending on several factors. Atmospheric diffusion, wind action, algae, and macrophytes introduce oxygen to the system. Dissolved oxygen levels are highest at the air/water interface, and decrease with depth. Depending upon the depth of the water and internal mixing, dissolved oxygen levels are often quite low at the bottom of the water column and even anaerobic just a few millimeters below the sediment. Figure 2-2 illustrates some of the major process that are important in treatment wetlands.

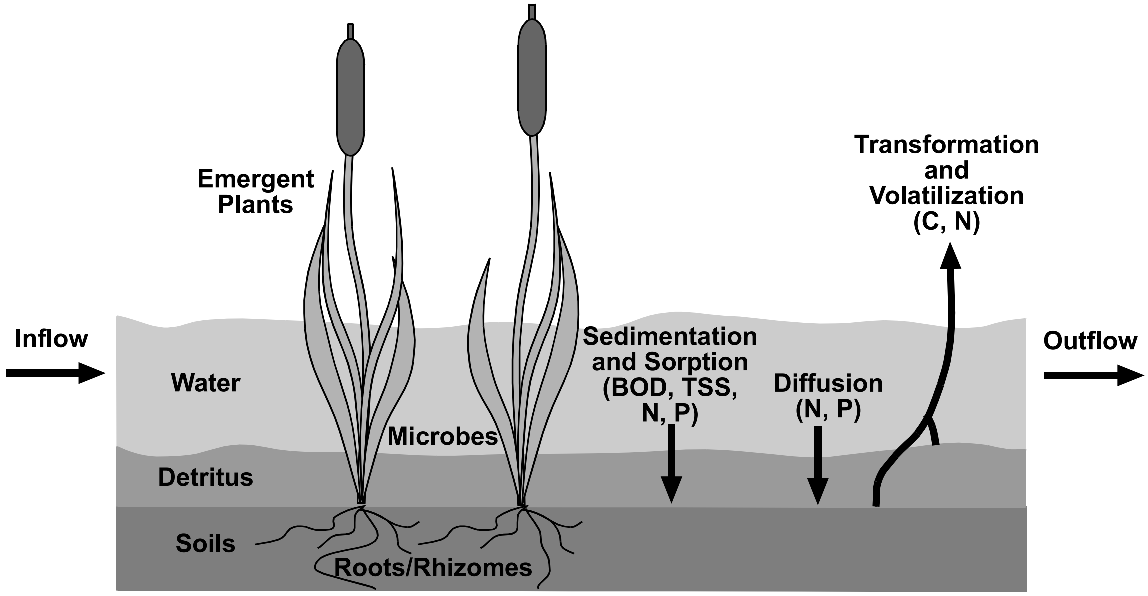


Figure 2-2. Processes Fundamentals in Treatment Wetlands.

SF wetlands are generally the least costly to construct, simplest to design, and provide the most valuable wildlife habitat. SF constructed wetlands provide greater flow control, less chance for hydraulic failure, and a diversity of design configurations and project goals compared to SSF constructed wetlands. Also, the aesthetic appeal, wildlife habitat, and recreational opportunities associated with SF treatment wetlands may be important to project goals.

2.1.2.2 Subsurface Flow Constructed Treatment Wetlands

Also known as reed beds, rock-reed filters, gravel beds, vegetated submerged beds, and the root zone method, SSF wetlands are constructed with a porous material for a substrate, such as coarse sand or gravel. Reed beds and rock-reed filters use sand, gravel or rock as substrates, while the root zone method uses porous soils. SSF treatment wetlands are designed and operated so that water flows below the ground surface through the substrate. No surface water should exist in these systems under normal flow conditions.

Advantages of SSF wetland treatment systems include increased treatment efficiencies, reduced mosquito breeding potential, reduced risk of exposing humans to drowning or pathogens, reduced wildlife exposure to toxics, decreased waterfowl use (desired near certain facilities such as airports), and increased accessibility for upkeep (no standing water). The substrate provides more surface area for bacterial biofilm growth than a comparable-sized SF. SSF wetlands are also better suited for cold weather climates since they are better insulated.

Volumetric efficiency in SSF systems is potentially greater than in SF constructed wetlands primarily because more surface area is available for attached biological growth in the treatment zone. This increased surface area results in greater removal of substances that are dependent upon microbial mass and not limited by other factors. Horizontal –flow SSF

wetlands typically have significantly higher average removal rate constants for BOD, organic nitrogen, and nitrate nitrogen; but have no apparent advantage for removal of TSS, total nitrogen, and total phosphorus than SF treatment wetlands. Since SSF systems are more efficient than SF systems for reduction of some pollutants, they may require less land area to treat the same wastewater. Saving land area is important at many installations and translates into reduced capital costs for land.

For best results, the media characteristics should be uniform throughout the bed except for the inlet and outlet zones that have coarser media. One potential design problem with SSF wetlands is surface flooding because the hydraulic conductivity of the media was not determined correctly and/or head loss through the media was correctly estimated. To ensure successful below ground operation, typical designs specify washed gravel of a specific size with an assumed decrease in hydraulic conductivity with maturation of the microbial populations.

Because the treatment zone is entirely underground and saturated, conditions in SSF wetland beds become anaerobic. Some oxygen is transferred from the atmosphere via plant leaves and stems to the roots. However, only a slight amount diffuses out of the rhizosphere and this dissolved oxygen is rapidly scavenged by aerobic and facultative microbes nearby. Therefore, useful oxidation reactions such as aerobic degradation of carbonaceous material and nitrification of ammonia nitrogen are limited by oxygen availability in SSF constructed wetlands.

On the other hand, data from many operational, full-scale systems shows that SSF CTWs treat many compounds of concern quite well. For instance, at normal mass loading rates biological oxygen demand (BOD) and total suspended solids (TSS) typically have removal efficiencies in the 80-90% range [24]. Also, many industrial contaminants are effectively and safely removed in these systems [25].

2.1.3 Constructed Wetland Contaminant Removal Mechanisms

CTWs, like natural wetlands, remove and/or degrade contaminants in water by a variety of mechanisms which can be categorized into one of three major groups: physical, chemical, or biological. Often, a contaminant will be affected by two or more mechanisms acting together or in sequence, depending upon its state and location within the wetland. For example, sediments are removed from the water column by the physical process of settling.

Metals, which may be adsorbed to these sediment particles are translocated to the wetland sediments by this process and subsequently reduced to sulfide salts by sulfate-reducing bacteria in the anaerobic zones of the wetland sediment. Organic contaminants are sorbed by sediment and biological particles and subsequently biodegraded by microbes in the sediments, or are taken up by plant roots. These are but a few of the many mechanisms present in treatment wetlands. Contaminant removal mechanisms are diverse and adaptable since they are part of a dynamic, living system that has the capability to adapt through high inherent biological diversity and species selection.

Contaminants which exhibit similar chemical and/or physical properties may be subject to the same removal mechanisms. Contaminants can be placed into generic mechanistic groups, depending on their chemical and physical properties. Table 2-1 summarizes some major groups of contaminants and their primary removal mechanisms in

treatment wetlands. Less significant mechanisms, including secondary, tertiary, or ultimate fate processes are not included. Precursor processes are also not included.

Contaminant removal mechanisms can act uniquely, sequentially, or simultaneously on each contaminant group or species. As an example, volatile organic compounds (VOCs) in contaminated groundwater are primarily removed through the physical mechanism of volatilization. However, additional mechanisms including adsorption to suspended matter, photochemical oxidation, and biological degradation, also play a role.

Major physical removal mechanisms in wetlands include settling, sedimentation, diffusion, and volatilization. Physical processes play an important role in contaminant reduction for both dissolved and particulate pollutants. The removal affects of these important physical processes, gives biological and chemical treatment processes the necessary time for effective treatment.

Gravitational settling is responsible for most of the removal of suspended solids. Gravity promotes settling by acting upon the relative density differences between suspended particles and water. Wetlands enhance this because of their relatively low water velocity and to a much lower extent the filtering effect of plant stems and leaves. The large relative area of the wetland compared to the influent water stream results in a decreased water velocity allowing dense objects to fall out of the water column while plant leaves and stems act to reduce wind-induced mixing and resuspension of settled particles.

Diffusion is the physical process of movement or mass transport of a dissolved substance from an area of high concentration to an area of low concentration. Diffusion distances in wetlands are relatively short due to shallow water depths and the close proximity of the three principal wetland sub-environments: atmosphere, water, and sediments.

Volatilization is a diffusion process, which occurs when compounds with significant vapor pressures partition to the gaseous state. Contaminant volatility increases with temperature. Thus, volatilization increases as sunlight heats the water column. Volatilization may also be a significant removal mechanism in the microbial breakdown products of organics.

Many pollutant-transforming chemical reactions occur in wetland water, detritus, and rooted soil zones. Most chemical reactions occurring in the soil zone and detritus layer are mediated by biological processes due to the high microbial activity in these zones. Other pollutant transforming chemical reactions include precipitation and redox reactions, ultraviolet radiation, complexation reactions (e.g. with humic acids), ion exchange, chelation, and soil incorporation.

Biological removal mechanisms include aerobic microbial respiration, anaerobic microbial fermentation and methanogenesis, plant uptake, extracellular and intracellular enzymatic reactions, antibiotic excretion and microbial predation, and die-off. High microbial activity is typical of wetland sediments because of the high rate of organic carbon fixation by wetland plant communities. The diverse microbial populations in the treatment wetland rooted soil zones, detritus layer, and submerged surfaces of plant leaves and stems are responsible for most pollutant transformations.

2.1.4 Fate and Transport

The environmental fate of contaminants entering a wetland includes elimination, transformation, immobilization, incorporation, and system exodus. The concentration of some pollutants may be reduced by more than one fate mechanism. Upon entering the wetland, transport mechanisms include diffusion, gravity settling, hydraulic travel through the wetland, vegetative translocation, and in some cases, transfer to groundwater flows. Plant and microbial growth nutrients may be assimilated and released by numerous generations within a wetland, resulting in high gross removals, spiraling from inlet to outlet, and a much smaller net removal. In the case of conservative elements such as phosphorus or trace metals, long-term storage in the wetland detritus and soil is responsible for most of the net removal. Further, each pollutant has its own chemical properties that result in variable affinities to each of the various endpoints.

Table 2-1: Primary Treatment Wetland Contaminant Removal Mechanisms in CTWs

Contaminant Group or Water Quality Parameter	Physical	Chemical	Biological
Solids Settleable and Suspended solids Turbidity	Sedimentation Settling Filtration		Microbial degradation
Oxygen Demands Biological oxygen demand (BOD_5) Chemical oxygen demand (COD)	Sedimentation Settling	Oxidation UV radiation	Microbial degradation
Metals Cu, Cd, Cr, Ag, Pb, As, Hg, Zn, Ni, Se	Sedimentation; Settling; Diffusion	Precipitation; Adsorption; Ion exchange	Microbial uptake; Plant uptake
Petroleum Hydrocarbons Fuels, oil and grease, alcohols, BTEX, TPH	Volatilization; Diffusion	Oxidation; UV radiation	Microbial degradation; Plant uptake
Synthetic Hydrocarbons PAHs, chlorinated and non-chlorinated Solvents, pesticides, herbicides, insecticides	Sedimentation; Settling; Volatilization Diffusion	Adsorption; Oxidation; UV radiation	Microbial degradation; Plant uptake
Nitrogenous Compounds Organic N, NH_3, NH_4, NO_3^{-2}, NO_2^-	Sediment Settling Diffusion	Mineralization Adsorption	Microbial uptake and transformation; Plant uptake
Phosphoric Compounds Inorganic and organic P	Sedimentation Settling Diffusion	Precipitation Adsorption	Microbial uptake; Plant uptake
Pathogens	Settling	UV radiation	Die-off; Microbial predation

Table derived from data presented in Horner and Skupien (1994)[26].

Wetlands sequentially degrade and eliminate most organic pollutants, other organic matter, and nutrients primarily through biological activity. Metals removal is often a biophysical consortium of processes including settling and bioutilization. An aerobic microbial process, which metabolizes compounds such as benzene or other organic matter into simpler products of CO_2 and H_20, is an elimination fate process.

Some chemicals will be transformed into less noxious or less hazardous substances while others will be translocated, immobilized, or concentrated. The majority of compound transformations and immobilization occurs as a result of biological activity within wetland soils, sediment, and detritus layers. The layers bind organic chemicals, inorganic compounds, and metals. At the same time, bound biodegradable compounds are either fully degraded or further transformed into usually less toxic compounds. Partially treated pollutants, transformed contaminants, and volatile compounds can exit a wetland through atmospheric diffusion, groundwater leakage, and the system outlet.

Metals and non-degradable compounds will tend to accumulate in wetland components. Most of the accumulation occurs in the soil and sediment layers. These layers bind contaminants well and become environmental endpoints. Most of the metals are removed from water by the soil layers. Metal removal rates can vary greatly depending upon the influent concentrations and hydraulic loading rates.

2.1.5 Role of Plants, Microbes, and Animals

CTWs are a diverse, complex, interrelationship of biota, including plants, microbes, and animals. Plants visible to the unassisted eye are called macrophytes and include the vascular, herbaceous, and woody species common to wetland environments. Microbes are microscopic organisms such as algae, fungi, and bacteria. Animals existing in wetlands include mammals, insects, invertebrates, fish, amphibians, reptiles, and birds.

Most of the pollutant removal activity in wetlands is partially or entirely dependent upon the action of a richly diverse, populous and opportunistic biotic community. Wetland treatment performance stems largely from the healthy growth of wetland flora and fauna and is dependent upon the continuing input of solar radiation to turn the biological flywheel. A large share of the pollutant transformation occurs at the microscopic level of the wetland foodchain occupied by microbial organisms. Production of reduced carbon by higher plant photosynthesis in treatment wetlands is the primary food source for these microbial organisms. Microbes selectively metabolize pollutants based on their needs and available food sources. They can remain dormant when food is absent and “called into action” as food sources become available.

Most wetland microbes are found in the sediment, soil, and litter layers. All living things, including microbes, require nutrients in the form of carbon, nitrogen and phosphorus compounds (as well as a varying range of other elements) for growth. Contaminants are largely composed of compounds containing these elements, and thus can serve as a food source for microorganisms which are capable of utilizing these substances. While some contaminants are poisonous or otherwise detrimental to higher life forms, the same contaminants may provide sustenance for genetically adapted microbes, at least in lower concentrations. The diversity of microbial life in a wetland confers the ability to treat a wide range of contaminants. For nearly every compound there exists a microbial pathway for degradation or a mechanism for uptake or sequestration. Even newly synthesized compounds elicit evolutionary adaptation through mutation as microbes make use of whatever nutrient source is available.

Microbial diversity is further supported by the gradation of aerobic to anaerobic zones in the litter, sediment, and soil layers. Each zone supports a unique, yet internally diverse, community of microorganisms. Even within the deeper anaerobic zones there exist “micro-”

aerobic and anoxic zones where anaerobic organisms can share metabolites with neighboring aerobic organisms and facultative species. Such microaerobic zones are found in the immediate vicinity of the root hairs of plants. This zone is called the rhizosphere, and is aerobic because plants leak oxygen from their root hairs. The symbiotic relationships between the plants and microbes are complex; plants and microbes often benefit one another, for instance, by exchanging nutrients or exudates.

Organisms in the anaerobic zone are effective in the removal of heavy metals by precipitating them as insoluble sulfide compounds. These metallic sulfides are biologically unavailable and sequestered in the wetland sediments. The diversity of the various wetland zones and the microbial communities in each of these zones and their intercommunication results in a wide variety of potential metabolic fate pathways for contaminants.

Wetland plants perform a number of important functions in treatment wetlands. Firstly, they serve to stabilize wetland soil and sediment and enhance the accretion of new sediments by their reduction of wind-induced resuspension of solids that settle out of the water column. Secondly, they are the primary autotrophic organisms in the wetland. They harvest the sun's energy and create biomass, serving as the first link of the microbial food chain. Plants also remove nutrients from the water such as nitrogen and phosphorus compounds, and trace elements and organics through biological uptake and surface adsorption.

During photosynthesis, carbon dioxide is consumed and oxygen is released. Submerged aquatic plants growing within the water column raise the dissolved oxygen level in the wetland surface water and deplete the dissolved carbon dioxide, resulting in an increased pH to near circumneutral pH levels. An examination of pH in treatment wetlands shows that typical operational pH levels range from 6.5 to 7.5 [13].

Rooted wetland macrophytes also actively transport oxygen from the atmosphere to the sediments. Some oxygen leaks from the root hairs into the rhizosphere, supporting aerobic and facultative anaerobic microorganisms in the otherwise anaerobic sediments and soils as previously discussed. Dense populations and high growth rates of emergent macrophytic plants in CTWs are critical to high pollutant removal rates due to all of the processes described above.

Plants also release carbon compounds in soluble forms such as carbohydrates, proteins, products of photosynthesis, which serve as a nutrient source for microbes which in turn may support other microbes. The result is a complex, synergistic system between aerobic, facultatively anaerobic and obligate anaerobic microorganisms for degradation of a wide variety of contaminants. Thus, a complex web of interactions occurs between plants and the diverse (perhaps hundreds or thousands of species) community of microorganisms.

Plants also control excess algal growth by intercepting sunlight. Algae are plants in themselves, releasing oxygen via photosynthesis, and are effective at removing nutrients from the surface water. However, excess algal growth within a treatment wetland can result in the release of undesirable levels of suspended solids to downstream receiving waters. A healthy stand of emergent vegetation obstructs sunlight from reaching the water surface and reduces the growth of undesirable algae in a treatment wetland. Plant death and decay helps build the important detritus layer where much of the microbe population resides.

Wetlands are complicated, living ecosystems in a constant state of flux. The role of each biological entity in the wetland ecosystem also changes somewhat over time. Some changes are seasonal such as plant growth and decay. Other changes are successional as a wetland matures. Additional fluxes arise from the changing conditions of influent water quality and constituents. Though complex and difficult to quantitatively define, it is important to be aware of the fundamental symbiotic and adaptable relationships between microbes, plants, and animals in a treatment wetland so that intelligent design decisions can be made.

2.1.6 Selection of SSF vs. SF CTW

The SSF CTW technology was selected for demonstration at the Westover ARF because of the following anticipated advantages:

- SSF systems may have higher rates of removal for BOD and COD (the principal measures of ADF concentration) than SSF CTWs, thereby reducing the wetland footprint area and allowing greater pollutant removal within the confined area available for this project
- SSF wetlands have minimal standing water, thereby reducing their attraction for wetland-dependent birds that might pose a BASH threat

No comparison between SF and SSF was possible within the time and budget constraints of this project. For that reason this project did not provide any information relevant to the possibility that SF CTWs might or might not be more cost effective than SSF CTWs for management of ADFs.

2.1.7 Design Criteria

The SSF CTW Technology Demonstration Project design is based on widely available hydraulic and chemical design tools that have been previously published [13,14]. An overall, first-order rate equation was used to determine the extent of pollution reduction expected. Final effluent concentrations for the parameters of concern were calculated based on Equation 1.

$$(C - C^*) = (Co - C^*)\, e^{(-k/q)} \qquad [1]$$

Where

C = effluent BOD_5 concentration, mg/L
Co = influent BOD_5 concentration, mg/L
C^* = irreducible background BOD_5 concentration, mg/L
k = overall, first order, areal rate constant, m/yr
q = hydraulic loading rate, m/yr

Design criteria relevant to SSF CTW Technology Demonstration Project are summarized in Table 2-2.

Table 2-2. Summary of Design Criteria for Subsurface Flow Constructed Treatment Wetlands

Criteria	Typical Values
Hydraulic Loading Rate, cm/d	5 – 17
First Order Areal-Based Removal, BOD_5, m/yr	150
Bed depth , m (ft)	0.60 (2)

The rate constant, k, was determined from an analysis of published k values from operational wetland systems. A look at treatment data from treatment wetlands built in cold climates suggests that k is independent of temperature for systems designed to treat BOD_5.

One critical design component of a SSF CTW is proper selection of the bed media. Initial design calculations (Equations 2 and 3) indicated a 1.7 in rock would be required to achieve proper subsurface-flow conditions under peak hydraulic loads. However, locally available material suitable for use as a bed media has only a 1.5 inch nominal diameter.

$$\Delta H = QL/k_f hW \qquad [2]$$

Where:

ΔH = change in water surface elevation (m)
Q = flow (m^3/d)
L = bed length (m)
k_f = final hydraulic conductivity (m/d)
h = bed depth (m)
W = bed width (m)

Assume:

$\Delta H < 0.02$ m for inlet and outlet zones, and
$\Delta H < 0.01(h) = 0.06$ m for the gravel bed
$k_f = 0.5(k)$ for large rock, and
$k_f = 0.1(k)$ for gravel

$$Dp = (k/12{,}600)^{0.5} \qquad [3]$$

Where:

Dp = particle diameter (cm)
k = clean media hydraulic conductivity (m/d)

In order to better understand flow dynamics the 1.5 inch rock was sampled and a geotechnical analysis was performed. Testing included calculation of bulk specific gravity (ASTM C-127), unit weight and porosity (ASTM C-29), and hydraulic conductivity (Modified ASTM D-2434). The modification to ASTM D-2434 consisted of running a falling head permeability test using a 6 inch diameter column. Since ASTM D-2434 is normally used for material in the fine gravel range (i.e. less than 15 mm), the modifications were needed to better measure conductivity of the relatively large rock (38 mm nominal

size). The results indicated that the long-term headloss effects of the 1.5 gravel media might result in short term surface water during peak flows. However, peak flows were expected to be of relatively short duration (less than 2 hours).

2.1.7 Storm Water Pollution Control

Constructed wetlands are widely recognized for to their ability to treat water with variable levels of contamination. There has been increasing attention in how natural systems can be used to help treat storm water pollution. The intermittent and high flow rates associated with many storm flows require a certain amount of storage for adequate treatment. Therefore, SF wetlands are preferred over SSF systems because of their ability to store larger volumes and assimilate large flows. SSF constructed wetlands can be used for storm water treatment as long as peak flows can be stored for later treatment or by-passed around the SSF wetland bed.

Storm water pollution results from runoff, atmospheric deposition, drainage, or seepage of contaminants. Major sources of storm water pollution include runoff from equipment storage areas, equipment maintenance areas, agricultural and dairy operations, and urban areas. Sediments and nutrients are the pollutants that cause most of the non-point source (NPS) storm water impacts to the nation's surface waters. These NPS sources are often harder to identify, isolate, and control than point sources because they draw upon the entire catchment area.

Stormwater runoff from urban, industrial, and agricultural areas usually contain low levels of contaminants and has high flow rates. Table 2-3 gives concentration data for typical storm water runoff sources. Typical sources of contamination in stormwater runoff include:

- Oil, grease, and gasoline from vehicles leaking onto roadways;
- Pesticides and fertilizers from agricultural and urban areas;
- Sediment from construction operations; and
- Metals from vehicle exhaust, rust, paint, tires, and engine parts.

Storm water pollution is of particular concern to the DoD because many discharge locations are near sensitive marine and estuarine ecosystems. The Navy usually occupies one of the last portions of land before discharge to the ocean. Navy owned outfalls may discharge NPS pollution, not only from the Navy installation but also from many sources further upland in the drainage basin.

Navy and DoD facilities can benefit from constructed wetland treatment of storm water pollution. Installations are required to minimize pollution from stormwater and snowmelt runoff through implementation of a stormwater pollution prevention plan. The plan requires the installation to implement “best management practices” or BMPs for each identified source and/or potential source of pollution. BMPs are implemented to prevent, control, or treat NPS pollution. DoD applications for using constructed wetlands as BMPs include runoff from: (1) industrial areas, (2) aircraft deicing areas, (3) roadway deicing operations, (4) parking lots, (5) vehicle maintenance and storage areas, (6) small arms ranges, (7) various training applications, (8) roads and other impervious surfaces, and (9) other urban areas. Also, a constructed wetland could be used for advanced treatment of stormwater before entering pristine or sensitive surface waters.

Constructed wetlands reduce the level of storm water contaminants before they reach the receiving waters by acting as a buffer between pollutant sources and ultimate receiving waters. Stormwater treatment performance is site specific, variable, and depends on the concentration and mass loading of contaminants. Table 2-4 gives some selected treatment data from free water surface stormwater wetlands. The table shows typical average removal efficiencies and some of the variability in performance of different treatment wetland systems.

Table 2-3: Stormwater Pollutant Concentration Data from Various Sources

Constituent	Urban Runoff (mg/L)	Industrial Runoff (mg/L)	Residential Runoff (mg/L)	Highway Runoff (mg/L)	Agricultural Runoff (mg/L)
BOD_5	20	9.6	3.6 – 20	--	3.8
Oil & Grease	2.6	--	--	30	--
TSS	150	94	18 – 140	220	55.3
TN	2.0	1.8	1.1 – 2.8	up to 3.4	2.3
TP	0.36	0.31	0.05 – 0.40	up to 0.7	0.34
Cadmium	0.0015	--	--	--	--
Chromium	0.034	--	--	--	--
Lead	0.140	0.20	0.07 – 0.21	0.55	--
Nickel	0.022	--	--	--	--
Zinc	0.20	0.12	0.046 - 0.170	0.38	--

Note: (1) -- indicates data not available

(2) Data reported as seen in original sources: Kadlec and Knight [13]; Horner, R. [27];

Table 2-4: SF Constructed Stormwater Treatment Performance at Selected Sites

Constituent	Percent Removal by Wetland					
	McCarrons MN	Hidden Lake, FL	Hidden River, FL	DUST Marsh, CA	Wayzata, MN	Orange County, FL
TSS	87	83	86	77	96	89
N (type)	24 (TN)	62 (NH_3)	79 (NH_3)	15 (NH_3)	- 44 (NH_3)	61 (NH_3)
TP	36	7	70	56	77	40
Lead	68	54	83	88	96	83

Note: Data is from Kadlec and Knight (1998)[28]

2.2 Previous Testing of the Technology

The application of constructed wetlands for enhanced biodegradation of glycol-based deicing compounds has been sufficiently developed for demonstration at the field-scale. Data have been reported from three pilot or full-scale systems CTWs (Table 2-5). One of the full-scale systems is located in the U.S. at Wilmington, Ohio (Airborne Express Airport) [29], another full-scale system is located in Ontario, Canada at the Pearson Airport [30], and a series of pilot systems have been built at the Heathrow Airport in Great Britain [8]. Pilot field testing of biological and constructed wetland systems strongly suggest the technology can effectively treat deicing runoff [8,16,17]. The latest data from a pilot scale reed bed (subsurface flow) constructed wetland study at London's Heathrow airport shows an average removal efficiency of 78 percent; a stable and shock-load resistant populations of glycol-respiring microbes (10^{-5} – 10^{-7} colony forming units (CFU)/g substrate dry weight). The reed bed's removal efficiency has steadily improved as the treatment bed matured.

Further, laboratory data that shows bio-utilization of glycols by hundreds of microbial cultures, by the number of full-scale, constructed wetlands successfully operating in cold climates [18,19,20,31], and by recently published data from Heathrow Airport's pilot-scale constructed wetland systems [8].

2.3 Factors Affecting Cost and Performance

Factors that affect the cost and performance of CTW systems can be summarized as follows:

- Cost
    - pretreatment and/or storage
    - CTW area
    - earthwork (cut and fill)
    - liner
    - gravel - media (SSF)
    - pump vs. gravity
- Performance
    - pollutant loading (influent volumetric flow rate and pollutant concentration)
    - temperature - decreased biological activity in winter months
    - plant community development and root penetration
    - clogging and hydraulic short circuiting

Median construction costs for SF CTWs are $18,050 per acre while the average cost is about $26,600/ac [13]. These costs are much higher for SSF CTWs with a median of $145,000/ac and an average of $219,000/ac. The majority of these construction costs are associated with earthwork and with gravel in SSF wetlands.

Table 2-5: Constructed Treatment Wetlands Used for Enhanced Biodegradation of Glycol-Based Deicing Compounds

Parameter	Lester B. Pearson International Airport, Toronto, Ontario	Heathrow International Airport, London, England		Airborne Express Airline, Wilmington, Ohio
		Pilot	Full-Scale	
Wetland Type	Vertical/Horizontal Subsurface Flow	Surface Flow, Subsurface Flow, Floating Reedbed	Floating Reedbed, Subsurface Flow	Reciprocation subsurface flow
Wetland Area	1 acre	Substrate beds 5m x 30m; Floating system 3m x 5m	2.7 acre Floating; 4.1 acres Subsurface Flow;	2 systems each approx. 3 acres
Substrate	clean sand over graded gravel layers (total depth of 3 feet)	gravel SSF	gravel SSF	gravel
Vegetation	*Phragmites australis*	*Typha latifolia, Typha angustifilia, Phragmites australis, Schoenoplectus lacustris, Iris pseudacorus*	*Phragmites australis*	---
Drainage Area	944 acres (70-80% impervious)	759 acres (80% impervious)	725 acres (80% impervious)	2,200 acre airpark (200 acres concrete ramps)
Design Flow	1 year return event (1 inch rainfall)	---	1.8 mgd (aerated storage basin upstream)	0.36 mgd Avg; 1.44 mgd Peak
Residence Time	24 - 48 hours	---	24 hours	
BOD Inlet	1,000 - 5,000 mg/L	3.9 kg/d Average	240 mg/L peak	100 - 20,000 mg/L
BOD Outlet	100 mg/L during deicing months, 15 mg/L otherwise	Removals: 30.9% (SF); 32.9% (SSF); 34% (Floating)	40 mg/L	---
Construction Cost	$2 million	---	$5 million	---
Reference	Flindall and Basran, 2001	Chong et al., 1998	Revitt et al., 2000	Arendt, unpublished

Performance of CTWs is closely tied to inflow pollutant load which is the product of flow and concentration. Secondary factors include temperature (relatively minor importance for BOD and TSS removal), hydraulic efficiency or the volume of the wetland actually in the flow path (very important at low effluent concentrations but less so at higher outflow concentrations), and water-filled void space or volume. This is especially important in SSF CTWs where the bed can fill with solids under some conditions of high inflow loads of mineral solids. Performance is also somewhat dependent upon system age. Young CTWs, especially SSF systems, may have immature development of microbial communities and

inadequate reduced carbon available for support of the full microbial flora. Time to develop a fully mature operational system with maximum possible performance may be several years under conditions of light or intermittent pollutant loadings.

2.4 Advantages and Limitations of the Technology

As with any new technology transitioning from the small scale to the field scale, technical and economical risks exist in concert with potential benefits. CTW technology implementation issues include ancillary environmental protection, land-use issues, cost effective treatment, adverse affects from high contaminant loadings (shock loading,) seasonal treatment performance variation because of cold winter temperatures, and bird and animal strike issues. Advantages and limitations were also compared with competing alternative wastewater treatment options.

2.4.1 Ancillary Environmental Issues

Constructed wetlands can provide numerous ancillary benefits in addition to cost-effective treatment. Some of these benefits are difficult to evaluate since they tend to be more perceptive in nature. One of these benefits relates to enhanced public perception of the DoD. Installation of a wetland demonstrates good stewardship of public lands, and responsible and tangible use of taxpayer money. Whereas some environmental issues result in paperwork and no “hard goods,” a treatment wetland is something that can be seen in a very real sense.

SSF treatment wetlands also illustrate an environmental stewardship ethic for DoD installations. SSF are not particularly attractive to wetland-dependent bird species because of the lack of surface water. However, SSF treatment wetlands are beneficial to the environment because they do not rely on continuing inputs of non-renewable fossil fuel subsidies that are required for conventional treatment processes.

Since SF treatment wetlands serve as wildlife habitat and provide recreational opportunities and/or food sources for humans, exposure risk should be considered. Toxic chemicals such as refractile organics and metals may concentrate in the sediment layers. Some species living in the sediment/soil (benthic organisms) could be susceptible to elevated levels of these substances, or they themselves may bioaccumulate them. Non-benthic animals may feed on these organisms, possibly resulting in biomagnification of the contaminant.

If significantly elevated levels of toxic pollutants are expected to occur in a wastewater, an ecological risk assessment should be performed prior to selection of a treatment wetland alternative, and in some cases may be required (e.g. sites in or near installation restoration sites). Generalizations from past experiences and assumptions from the current state of knowledge will typically suffice for most feasibility studies.

Treatment wetlands can have usage limitations due to land issues, public or political priorities, treatment constraints, and ecological considerations. If these issues are not addressed and resolved prior to implementation difficulties, limited success, or failure may result. Therefore, potential limitations should be evaluated during project planning and analysis of alternatives.

2.4.2 Land Issues

Constructed wetland land issues include land availability and suitability, change in land use or classification, conflicts with habitat of endangered species, hydrology changes to local soils, creation of mosquito breeding potential, and potential for accumulation of hazardous substances in the detritus and sediment.

Depending upon the flows, contaminant types and concentrations, and treatment goals, a constructed wetland may require a considerable area of land. Since land costs are generally highest in areas where wetlands could provide the most benefit, i.e. urban/developed areas, the areal requirements and consequent land costs may occasionally be a constraint for constructed wetland implementation. If land is already owned and available, such as by a municipality or other government agency, then the total project cost will be lower, and land costs may not be an important issue (except for land use opportunity loss). Many DoD installations may have suitable land available for uses such as construction of treatment wetlands. Furthermore, treatment wetlands can be sited at DoD facilities in areas that serve as limited use areas such as buffer zones since the system operates without human intervention once established. Treatment wetlands can also be converted to other uses relatively quickly during times of critical need, as they are not regulated the same as existing, natural wetlands.

Land suitability relates to the ease with which available land can be converted to a wetland. Factors include topography, site soils and geology, existing vegetation, contaminated soil and water, underground and overhead utilities, adjacent land uses, etc. For instance, sites with steeply sloping topography are more costly to use for wetland construction since large cut and fill volumes and/or retaining walls may be necessary. Thus land availability does not necessarily mean that it is ideal or even suitable for a constructed treatment wetland.

Wetland construction will probably result in a loss of existing upland habitat (as opposed to existing wetland, lowland, or former wetland habitat) and should be weighed relative to creation of wetland habitat. Since wetland habitat is usually a premium, loss of upland grassland, agricultural land, forest, etc. habitat is usually a non-limiting constraint.

Finally, the inundation of water in a given area may have impacts beyond the wetland site. For example, soils beyond the wetland boundary can be subject to sustained saturated conditions. Plants found in upland areas cannot survive continuous or frequently saturated soil conditions and may be adversely affected. Therefore, an assessment of site and vicinity groundwater, soil characteristics, and geology should be performed.

2.4.3 Public Nuisance Issues

Subsurface flow wetlands possess virtually none of the features that could hinder public support. Any poorly maintained treatment wetland can become unsightly due to excessive algal growth or flotsam garbage build-up and poorly designed/maintained SF constructed wetlands may also become mosquito breeding grounds. Because flow is below ground at all times for properly design SSF wetlands, these potential problems of SF wetlands can be avoided altogether when using these systems.

2.4.4 Treatment Issues

Continuous treatment requirements can limit constructed wetland applications. Since constructed wetlands are natural systems with unique removal processes, certain treatment constraints exist that can occur at startup or even during regular operation. However, constraints exist for all pollution control devices; no technology, either man-made or based upon natural process, can treat all of a given pollutant all of the time. Adverse affects upon biological systems such as a constructed wetland can occur when subjected to high contaminant loadings. High COD and BOD loadings are expected from deicing activities and thaws of snow pack with ADF accumulation. These shock loadings could potentially harm wetland biota. However, data from the Heathrow wetland beds suggest otherwise. These beds were intentionally shock loaded by adding pure ADF along the inlets during performance testing. Water and sediment samples taken before and after each glycol dosing indicate that most of the wetland plants and substrate microorganisms show little adverse effect from the high dosing levels. Only one plant, the aquatic macrophyte *Typha sp*., showed signs of maladjustment to the high loadings.

Constructed wetlands have operational performance limitations because of their biological nature and variable influent loadings. Biological systems can adapt to environmental changes, such as contaminant concentration, but only within an acceptable range. Changes beyond that range may severely impact the functioning of the system for an extended period of time, due to the time for recovery of living organisms. Shock loading of a biological system beyond its buffering capacity is almost certain to lead to system failure. Buffering capacities of wetlands are largely proportional to their volume, the larger the wetland, the greater its ability to handle elevated loadings. Wetlands adjacent to industrial areas where concentrated spills of toxic substances may occur should have protective devices (e.g. buffering basins) installed upstream to protect the system from shock loadings.

Another potential issue of concern is the impact of decreased biological activity in winter months when it is most needed to treat ADFs. Numerous studies demonstrate the effectiveness of treatment wetlands for BOD removal in cold climates [21]. Detailed research conducted at Listowell, Ontario demonstrated that BOD, suspended solids, and phosphorus net removal rates in a constructed wetland were unchanged with respect to season and temperature [33]. Only the net rate of nitrogen removal was diminished during the winter months. Other research has indicated that BOD removal rates may be reduced at low temperatures if the influent BOD loading is very high [34]. None of the glycol treatment wetlands have yet reported performance data at high influent loads. Since glycols have high BOD content, and no nitrogen, performance of these systems in cold climates is a critical research question.

A time lag necessary for initial plant growth and wetland function establishment is an unavoidable requirement with constructed wetlands. A constructed wetland will generally not become fully functional (90% of design) as a treatment system for at least two months and as long as one or two growing seasons. Transplanting of seedlings or rootstock will help to establish the wetland more quickly. Systems planted with seedlings can reach full or near full coverage in two months during the growing season in semi-tropical climates (e.g. Florida) but may take up to 3 or more years in northern climates.

Cooler climates such as Seattle, Washington require three or four months of the growing season [28]. Research by the Institute of Terrestrial Ecology indicates that reed-bed seedling transplants may result in complete cover in one growing season [24]. Nevertheless, reduced pollutant removal should be expected while the plants and their associated biochemical processes become established during the first two or three growing seasons.

2.4.5 Bird and Animal Strike Hazard Issues

Bird and animal strike hazard (BASH) issues are important at all airports. While wildlife is attracted to all types of upland and wetland habitats, the construction of treatment wetlands, stormwater ponds and impoundments, and waste storage lagoons is discouraged within 5 miles of turbine engine runways [35]. Frequent mowing of vegetation adjacent to runways and elimination of open water roosting and feeding by wildlife, especially larger birds (ducks, gulls, geese) and flocking birds (blackbirds, starlings, grackles) are methods for reducing BASH at military and commercial airports.

Some BASH exists at all airports, even those that implement stringent control measures. This is because upland grassy areas are also attractive to browsing wildlife such as deer and to small birds and mammals that are the prey for larger predators such as hawks, owls, foxes, and coyotes. Also, many airports are currently adjacent to natural and existing wetlands and water bodies that have large populations of indigenous wildlife.

In considering a constructed treatment wetland for control of water quality problems resulting from the use and release of ADFs, it is important to use a form of the technology that is least attractive to wildlife. The SSF CTW category fills this role because there is no standing water present in the treatment cell(s). Lack of standing water makes SSF CTWs unattractive habitat for waterfowl and for flocking blackbirds. However, relatively tall vegetation is an important aspect of the SSF CTW technology. As described above, these plants are important for their high biomass production (reduced carbon important for microbial growth) and because of their deep rooting into the gravel bed. Frequent mowing of wetland plant growth is not an option because of its impact on treatment performance.

2.4.6 Comparison with Competing Alternatives

Advantages and limitations of CTW and competing wastewater treatment technologies in the attenuation of ADF runoff are summarized in Table 2-6 and include:

- SSF CTW
- Recover / Recycle / Reuse
- Ponds and Lagoons
- Anaerobic Fluidized Bed
- POTW

Table 2-6: Advantages and Limitations of Various Wastewater Treatment Technologies

ADVANTAGES	DISADVANTAGES
Subsurface Flow Constructed Treatment Wetland	
• No BASH • significant treatment • avoids POTW disposal • no collection required • low O&M costs • No deicing pads needed • collects most of ADFs generated from primary deicing pad • cost effective • if properly metered hydraulically, can treat high and low strength wastewaters • treats non-ADF stormwater contaminants	• large land area requirements • requires retention / detention for peak hydraulic loads • performance during extremely cold conditions • time-lag from construction until performance at maturity • ADF stormwater and general stormwater commingled • Moderate capital costs
Recover / Recycle / Reuse	
• eliminates discharge requirements • no POTW discharge requirements • can be cost effective if volume and concentrations of ADF are significant	• must collect high concentration ADF stormwater (>10% glycol) • requires dedicated deicing pads, containment, and collection to get high concentration glycol • disposal / discharge required for dilute wastewater • high operation / maintenance costs
Ponds / Lagoons	
• can be used for hydraulic load equalization and treatment • may provide treatment during holding periods • high capital costs	• may require aeration and chemicals • high operating cost for electricity, chemicals and labor • BASH • Generally requires POTW discharge with associated charges
Anaerobic Fluidized Bed	
• > 90 % COD reduction • reduces glycol from 4,800 to 1,500 mg/L to ND	• high capital cost $3.2 million • requires retention of stormwater

Table 2-6: Advantages and Limitations of Various Wastewater Treatment Technologies

ADVANTAGES	DISADVANTAGES
• methane generated during operation is used for process and space heating • discharge to POTW or spray irrigation to land • removes tolyltriazoles	• high operating costs • more likely to need repair and upkeep (e.g. granular activated carbon)
POTW	
• low capital cost because may not require treatment / recycle • can be cost effective at some locations $0.056 / lb COD at Minneapolis – St. Paul	• not all POTWs accept wastes • slug loads disrupt POTWs • can be expensive > 500k / yr at Denver • need to collect, contain, separate, and store ADF waste from stormwater • may require pretreatment / storage • may require significant airport infrastructure changes

[1] vacuum trucks, deicing pads, stormdrain inserts

3. Demonstration Design

3.1 Performance Objectives

Table 3-1 summarizes the performance objectives of the CTW Technology Demonstration Project as published in the Final Demonstration Plan [36]. For demonstration purposes, each objective consists of a performance criterion and a corresponding performance expectation or metric.

Table 3-1. Performance Objectives of the CTW Technology Demonstration Project

No.	Performance Objective	Expected Performance and Metrics
1	Reduced Cost	Annual cost <$2,500 or annualized cost <$1/lb BOD/yr
2	Slug load treatment	> 80% reduction when [BOD_5] > 500 mg/L
3	NPDES permit compliance	[BOD_5] < 30 mg/L (monthly mean)
4	Readiness	Improved deicing logistics and flight scheduling
5	Land use	No BASH impacts; no odors

3.2 Selecting Test Sites/Facilities

A number of DoD air bases were considered for the proposed SSF CTW Technology Demonstration Project. The air bases that were mostly highly ranked as candidates for this demonstration were:

- Whidbey Island NAS, Washington
- Fairchild AFB, Washington
- Westover ARB, Massachusetts

Considerable work had already been conducted at Westover ARB concerning the effects of deicing on receiving waters, including natural wetlands. This previous work and the strong interest shown by environmental personnel at the base were the primary factors in selecting Westover ARB as the top candidate for the demonstration project.

3.3 Test Site/Facility Characteristics/History

3.3.1 Historical Perspective

Prior to construction of Westover ARB, the area where the Base now resides consisted mainly of tobacco fields. In 1939, following the Nazi invasion of Poland, a 7.5 mile tract of land was chosen for the construction of the Northeast Air Base, which was to

serve as an important link in the chain of East Coast defense. A portion of the land was acquired by condemnation proceedings. The airfield was dedicated later in that same year as Westover Field in honor of Major General Oscar Westover. Major General Westover was one of the founders of the Army Air Corps; he served as its chief for a year and a half before dying in a plane crash in 1938 at the age of 55. The base was formally dedicated in April 1940, and, by the next year, was considered the largest in the United States.

During World War II, the base served as a training and overseas transition station, and was used primarily to train fighter pilots. In 1946, the base became one of the largest domestic and transatlantic passenger-freight aerial ports on the eastern seaboard.

The Strategic Air Command, flying B-52 and KC-135 aircraft, assumed control of the base in 1955. At that time, the Eighth Air Force Headquarters moved to Westover Air Force Base, where it remained for 15 years. In 1956, the Headquarters of the 57th Air Division and the 99th Bombardment Wing, including two B-52 squadrons, a refueling station, the 99th Combat Support Group, and the U.S. Air Force Regional Hospital, were transferred to Westover Air Force Base. The 57th Air Division was deactivated in 1969.

Phase down of the Base was announced by the Department of Defense in 1973. On April 1, 1974, deactivation ceremonies of the 99th Bombardment Wing ended the active duty role of Westover ARB. In the same year, the Air Force Reserve (AFRES) took over jurisdiction of the base with the activation of the 439th Tactical Airlift Wing (TAW). This unit operated C-123, C-130B and C-130E aircraft until 1987 when it was redesignated as the 439th Military Airlift Wing (439 MAW) and converted to C-5A aircraft.

In 1989, Air Force Reservists and C-5 aircraft from the 439 MAW, in conjunction with active-duty crews and aircraft, transported equipment and supplies to Panama to ensure the canal's continued operation and to protect U.S. citizens and resources located there. In December 1990, the 439 MAW was activated and supported airlift operations as Westover ARB became a major staging base in support of Operation Desert Shield. During Desert Shield and Desert Storm, more than 63,000 military passengers and 121,000 tons of cargo flowed through Westover ARB to and from the Persian Gulf with more than 3,600 aircraft transitioning through the Base. At that time, Westover ARB was in operation full-time with 1,500 activated Reservists living on base. Westover ARB performed maintenance on all aircraft, and served as command and control for incoming and outgoing military air traffic.

In 1992, the 439 MAW was redesignated as the 439th Airlift Wing (439 AW). In March 1997, AFRES was elevated to a major command in the USAF, and named the Air Force Reserve Command (AFRC).

3.3.2 Location and Existing Mission

Westover ARB is composed of approximately 2,511 acres of land within the communities of Chicopee and Ludlow in the northern portion of Hampden County, Massachusetts (Figure 1-2). The Base is bordered by or is in close proximity to the Cities of Holyoke and Springfield; and the Towns of West Springfield, Grandby, and South Hadley. Westover ARB is located 35 miles north of Hartford, Connecticut; and 90 miles west of Boston, Massachusetts. The Base is located in the Pioneer Valley Region, which encompasses 43 municipalities within Hampshire and Hampden Counties along the Connecticut River.

The Base is situated approximately 2 miles east of the Connecticut River, and is traversed and/or bounded by Cooley and Stony Brooks.

State Route 33, the main thoroughfare providing access to Westover ARB, is located less than one mile west of the Base. Approximately two miles southwest of the Base, State Route 33 intersects with Interstate 90 (the Massachusetts Turnpike), an east-west route between Boston and New York State. Interstate 91 runs north-south approximately 5 miles west of the Base.

Westover ARB is home to the 439th Airlift Wing (439 AW) of the Air Force Reserve Command (AFRC). The 439 AW operates and maintains sixteen C-5 aircraft, representing five percent of United States' total airlift capability. Westover ARB's vision is to build on their status as the largest mobility and reserve training base in the northeast, and thereby provide a Northeast Reserve Training Center that is also available as a fully operational Air Force Base.

The Base has two active runways, Runway 05-23, which is 300 feet wide by 10,600 feet long, and Runway 15-33, which is 150 feet wide by 7,050 feet long. Runway 05-23 is oriented approximately southwest to northeast, while Runway 15-33 is oriented approximately northwest to southeast. A series of taxiways extending from the flightline parking apron provide access to the runways.

The activities and operations at Westover ARB are grouped by functional areas and land use categories, including aviation support, residential, commercial, industrial, medical, administrative, public facilities/recreation, and open space. The two primary land use categories are aviation support and industrial activities, which account for more than 50 percent of all facilities and square footage on Base.

Although the predominant land use surrounding the Base is residential, a large percentage of land is devoted to commercial and industrial uses, with thirteen percent of the total land in the region consisting of cities and towns. Areas to the north and east of the Base consist mostly of rural communities with large agricultural and recreational uses; bordering the Base to the south and west is the town of Chicopee. In 1990, the valley area had a population of 278,211, with the Base employing 1,200 full-time civilians, 500 full-time reservists, and 2,800 part-time (reservist).

3.3.2 Site/Facility Characteristics

The SSF CTW Technology Demonstration Project is located in the Southeast section of the Westover ARB. Wastewater from aircraft deicing performed on the primary jet parking ramp is collected and conveyed by the storm sewer system through Outfall 001 (Figure 1-3).

Outfall 001 drains a 172 acre watershed with 106 acres (62 percent) of the area being impervious. When storm flows are less than about 3 mgd, water in the storm sewer is diverted to an existing 35,000 gallon O/W separator for pretreatment prior to discharge (Figure 3-1). The O/W separator receives a baseflow of approximately 24,000 gal/d by way of groundwater inputs. When storm flow is greater than about 3 mgd, excess water bypasses the separator and discharges directly into Cooley Brook, which discharges into the Connecticut River about two miles away.

Site soils are sandy with some rocks. Groundwater at the site varies from about 2 feet to over 10 feet below the original (pre-construction) ground surface depending on location and season. The climate at Westover ARB is continental temperate with cold winters and warm summers. The Hampden County area averages 138 days each year with average temperatures less than 33 degrees F[37]. The mean annual precipitation for a 20-year period-of-record (1969-89) was 42 inches. Average annual snowfall is 49.7 inches, with an average of 12 days per year with greater than 1.5 inches of snow recorded.

Figure 3-1. Outfall 001 Oil / Water Separator

3.4 Present Operations

Westover ARB performs deicing/anti-icing operations on its aircraft and runways, respectively, during snow storms and freezing rain events (Figure 3-2). The application of deicing chemicals generates contaminated runoff that can enter the storm sewer system and severely impair surface water quality in adjacent surface waters.

At Westover ARB, deicing can be conducted numerous times throughout the winter, depending upon weather conditions. Westover ARB currently uses propylene glycol for aircraft deicing at a 20-30/80-70 percent glycol/water ratio. Propylene glycol use during the past six winter seasons was: 2,655 gallons (FY 1998), 8,175 gallons (FY 1999), 3,715 gallons (FY 2000), 6,775 gallons (FY 2001), 14,730 gallons (FY 2002), and 76,150 gallons (FY 2003) for an average of 18,700 gallons per year. An average of approximately 12,880 gallons per year (FY 1999 – FY 2003) was used within the Outfall 001 watershed area. Detailed deicing logs for the Westover ARB are presented in Appendix C. Although the quantity of deicing chemicals used at the base is low compared to commercial airports, Westover ARB continues to use procedural and structural BMPs to minimize the amount of deicing runoff that enters surface waters. Procedural BMPs used by maintenance personnel involved in deicing operations include the following:

Figure 3-2. ADF Release to Ground After Deicing

- Use of maintenance hangars to prevent snow and ice accumulation on scheduled aircraft;
- Manual snow removal first before use of propylene glycol;
- Use of Pads 05 and 23 as secondary deicing locations;
- Primary deicing operations on the east ramp (Echo 5, 6, 8, or 13) over existing storm sewer drains to Outfall 001; and
- Documentation of all propylene glycol use.

Since 1991, Westover ARB has reduced the amount and toxicity of ADF runoff that enters the storm sewer system through the use of these BMPs.

3.5 Pre-Demonstration Testing and Analysis

Baseline data is critical for the comparison to operational data collected during the SSF CTW Technology Demonstration Project. Baseline sampling was collected at the site from February 1994 through March 2001. Table 3-2 summarizes the surface water quality data collected in the O/W separator and Cooley Brook during this period. Time series plots are presented in Appendix D. BOD reductions as a result of the demonstration project were assessed against the background of pre-project pollutant releases from Outfall 001.

Table 3-2. Baseline Water Quality Summary

Parameter	Statistics	O/W Inflow	Outfall 001	Cooley Brook
Ammonia (mg/L)	Average		0.36	
	Maximum		0.44	
	Minimum		0.27	
	StdDev		0.09	
	N		3	
	Min Date		1/17/01	
	Max Date		1/19/01	
BOD (mg/L)	Average		179	
	Maximum		1800	
	Minimum		1.00	
	StdDev		386	
	N		103	
	Min Date		2/1/94	
	Max Date		3/15/01	
COD (mg/L)	Average		1255	7.5
	Maximum		21500	7.5
	Minimum		2.50	7.5
	StdDev		3432	---
	N		98	1
	Min Date		2/1/94	1/19/01
	Max Date		3/15/01	1/19/01
Nitrate (mg/L)	Average		1.52	

Table 3-2. Baseline Water Quality Summary

Parameter	Statistics	O/W Inflow	Outfall 001	Cooley Brook
	Maximum		1.66	
	Minimum		1.42	
	StdDev		0.12	
	N		3	
	Min Date		1/17/01	
	Max Date		1/19/01	
Nitrite (mg/L)	Average		0.08	
	Maximum		0.12	
	Minimum		0.03	
	StdDev		0.05	
	N		3	
	Min Date		1/17/01	
	Max Date		1/19/01	
PropyleneGlycol (mg/L)	Average	250	1892	
	Maximum	250	11000	
	Minimum	250	25.00	
	StdDev	---	2713	
	N	1	33	
	Min Date	1/24/01	1/5/01	
	Max Date	1/24/01	3/15/01	
TKN (mg/L)	Average		0.41	
	Maximum		0.50	
	Minimum		0.12	
	StdDev		0.19	
	N		4	
	Min Date		1/27/00	
	Max Date		1/19/01	
TOC (mg/L)	Average		1306	
	Maximum		7517	
	Minimum		0.50	
	StdDev		1885	
	N		32	
	Min Date		1/5/01	
	Max Date		3/15/01	
TP (mg/L)	Average		0.69	
	Maximum		1.00	
	Minimum		0.49	
	StdDev		0.27	
	N		3	
	Min Date		1/17/01	
	Max Date		1/19/01	
Turbidity (NTU) [1]	Average		2.03	
	Maximum		4.87	
	Minimum		0.45	
	StdDev		2.46	
	N		3	
	Min Date		1/5/01	
	Max Date		1/9/01	
Dissolved Oxygen (%)	Average		56.1	
	Maximum		183	
	Minimum		8.9	
	StdDev		40.3	

Table 3-2. Baseline Water Quality Summary

Parameter	Statistics	O/W Inflow	Outfall 001	Cooley Brook
	N		1918	
	Min Date		10/20/00	
	Max Date		3/15/01	
Flow (gpm)	Average		127	
	Maximum		3477	
	Minimum		0	
	StdDev		228	
	N		2071	
	Min Date		12/19/00	
	Max Date		3/15/01	
pH (units)	Average		7.16	
	Maximum		8.52	
	Minimum		5.94	
	StdDev		0.50	
	N		1440	
	Min Date		10/20/00	
	Max Date		3/15/01	
Redox (mV)	Average		384	
	Maximum		770	
	Minimum		-146	
	StdDev		254	
	N		1919	
	Min Date		10/20/00	
	Max Date		3/15/01	
Salinity (ppt)	Average		0.98	
	Maximum		5.0	
	Minimum		0.00	
	StdDev		0.7	
	N		1919	
	Min Date		10/20/00	
	Max Date		3/15/01	
Specific Conductance (mS/cm)	Average		1.91	
	Maximum		8.92	
	Minimum		0.12	
	StdDev		1.24	
	N		1919	
	Min Date		10/20/00	
	Max Date		3/15/01	
Temperature (^oC)	Average		5.20	
	Maximum		12.2	
	Minimum		0.62	
	StdDev		2.66	
	N		1919	
	Min Date		10/20/00	
	Max Date		3/15/01	
Turbidity (NTU) [2]	Average		6.84	
	Maximum		19.7	
	Minimum		1.17	
	StdDev		4.49	
	N		1918	
	Min Date		10/20/00	
	Max Date		3/15/01	

Notes: [1] lab measurement; [2] field measurement (hyrolab)

Detailed data from baseline surface water sampling events are presented in Appendix E. Samples were collected from Cooley Brook, Outfall 001 (discharge from the O/W separator), and inflow to the O/W separator.

3.6 Testing and Evaluation Plan

3.6.1 Demonstration Set-Up and Start-Up

Construction of a 0.6-acre field-scale SSF CTW system began in August 2001 for treatment of ADF runoff and effluent following pretreatment from the existing 35,000 gallon O/W separator (Figure 3-1). The CTW system was completed in June 2002 with the planting of *Phragmites sp*.

A cross-section of the CTW is presented in Figure 3-3 identifying key design criteria of the system. Design criteria include the following:

- Bed surface elevation approximately 204 ft msl
- Bed depth 60 cm
- Bed bottom slope 0.0001
- 30 mil PVC liner on compacted native soils with a 6-inch compacted sand bed between the liner and the gravel
- Bed width approximately 230 ft
- Bed length approximately 120 ft
- Bed area approximately 0.63 ac
- Levee slopes 3:1 (H:V)
- Levee freeboard above gravel bed 2 ft
- Inlet and outlet rock zones approximately 10 ft wide with minimum 6-in rock
- Gravel bed with minimum 1.7-in washed gravel
- Media porosity 0.47
- Inlet pipe buried in rock zone
- Outlet pipe buried at bottom of outlet rock zone
- Outlet in vertical culvert manhole with flexible outlet hose
- Site drainage swale upgradient of CTW cell
- Wetland residence time 1.85 days ($t = V/Q$)
- System residence time 2.2 days, including O/W separator
- Hydraulic loading rate 14.6 cm/d
- Peak wetland flow 1,500 m^3/d (0.4 mgd)

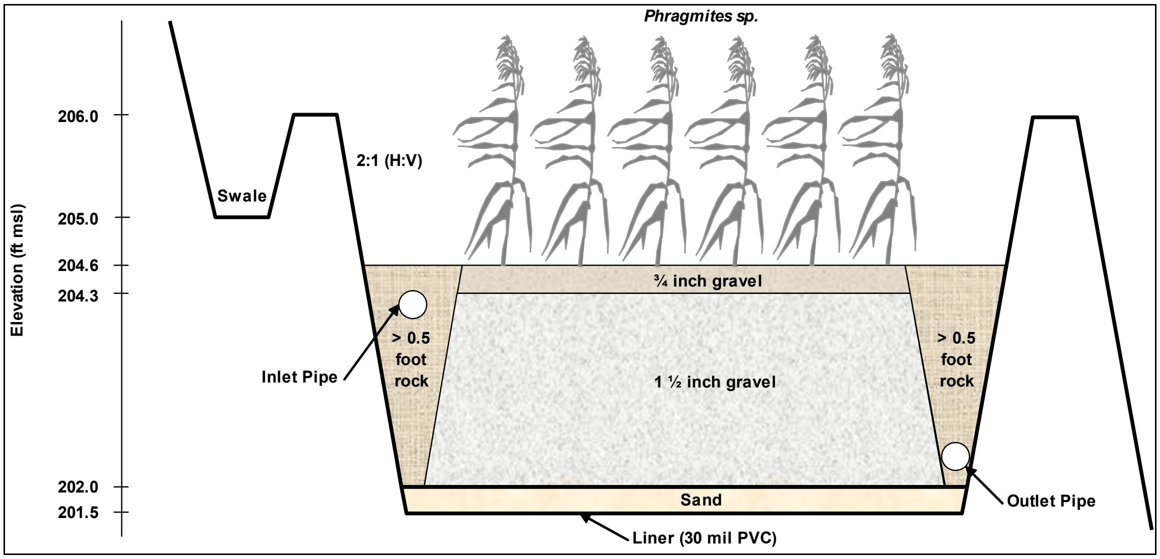


Figure 3-3. Horizontal Subsurface Flow CTW Cross-Section at the Westover Air Force Reserve Base, Chicopee, MA

Figure 3-4. SSF CTW After *Phragmities* Planting (July 2002)

A Hydrolab H_20 Multi-probe was installed in October 2000 to measure baseline pH, temperature, oxidation-reduction potential (Eh), conductivity, salinity, and turbidity in the O/W separator. Two pressure transducers were also installed to monitor water depths in the O/W separator and wetland outlet pipe, prior to discharge to Cooley Brook. Data from the Hydrolab and pressure transducers were reported to a Handar data logger and retrieved periodically by Westover ARB personnel.

Figure 3-5. SSF LAR Quick-TOC® Analyzing System

Wetland planting of *Phragmities sp*. rhizomes was completed in June 2002. Approximately 3 inches of ¾ inch diameter gravel was placed on the surface for a planting medium of about 2,000 bare root rhizomes planted on 3-foot centers (**Figure 3-4**). The source of wetland plants was from Southern Tier Consulting in West Clarksville, New York.

A LAR Quick-total organic carbon (TOC)® continuous water and process online analyzing system was installed onsite in December 2002 to measure total carbon

(TC) concentrations in the O/W separator and at the wetland outflow to Cooley Brook (Figure 3-5).

Two additional pressure transducers (Infinities USA, Inc.) were installed in December 2002 at the O/W separator and at the wetland outflow box. Water levels in the O/W separator were used to estimate the amount of wetland bypass flow through Outfall 001. Water levels in the wetland outlet box were used to estimate flows being discharged to Cooley Brook and also to monitor water levels in the wetland.

3.6.2 Period of Operation

The period of operation for the CTW Demonstration Project is indicated in Table 3-3.

Table 3-3. Period of Operation

Item	Start Date	End Date	Duration (Days)
Baseline Monitoring	01OCT00	15MAR01	165
Construction	01AUG01	01JAN02	153
Establishment	15JUN02	30SEP02	107
Experiment	01OCT02	6MAY03	217

3.6.3 Amount/Treatment Rate of Material to be Treated

The CTW system was designed for an event mean flow of 100,000 gpd (69 gpm) with peak loadings approaching 400,000 gpd (278 gpm). The actual estimated mean flow to the CTW during storm events was about 170,000 gpd (118 gpm) with a peak flow of 506,160 gpd (352 gpm). These flows are considerably higher than the planned design flows. The average flow to the CTW (baseflow and storm events) during the December 17, 2002 through May 6, 2003 period was 70,315 gpd (49 gpm). Bypassed flow over the O/W Separator V-notch weir for the same period averaged 64,570 gpd (45 gpm) with an instantaneous peak flow estimated at about 6,000,000 gpd (4,100 gpm). Total flow to the Oil / Water Separator averaged 135,360 gpd (94 gpm) with an estimated peak flow of about 6,200,000 gpd (4,300 gpm).

Figures 3-6 and 3-7 illustrate the water elevations and estimated discharge flow frequency curves from the O/W separator and CTW. Figure 3-8 illustrates the cumulative discharge curves from the wetland and bypassed flows from the O/W Separator. During the experimental performance period, the wetland treated approximately 52% of flows that entered the Outfall 001 O/W Separator.

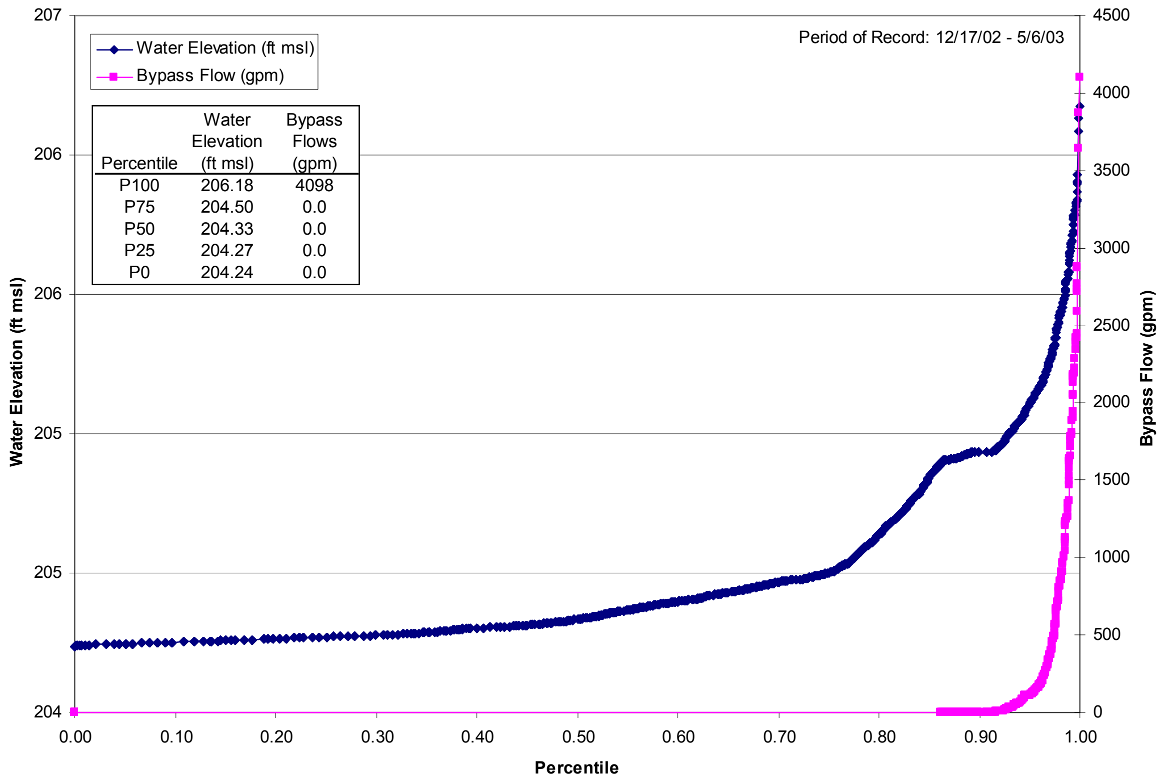
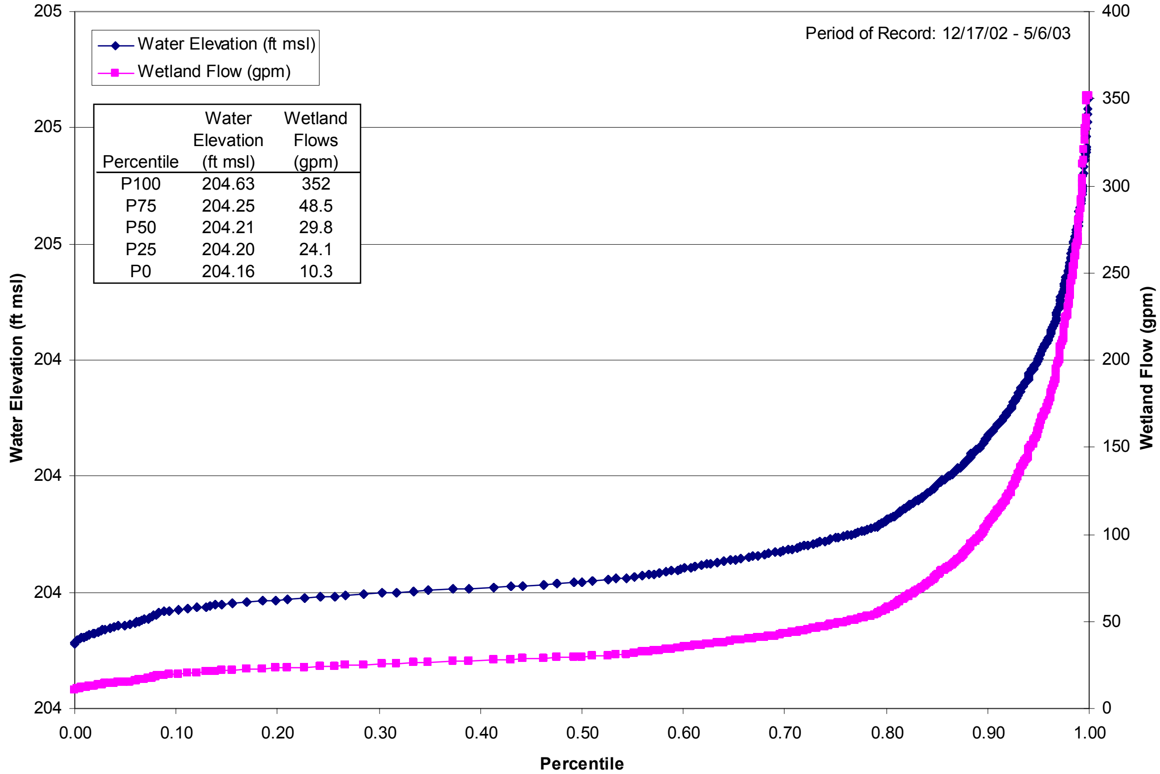


Figure 3-6. Hourly Water Elevations and Bypass Flow Percentiles in the Outfall 001 Oil/Water Separator



Percentile	Water Elevation (ft msl)	Wetland Flows (gpm)
P100	204.63	352
P75	204.25	48.5
P50	204.21	29.8
P25	204.20	24.1
P0	204.16	10.3

Figure 3-7. Hourly Water Elevations and Wetland Flow Percentiles in the Westover Horizontal Subsurface Flow Wetland

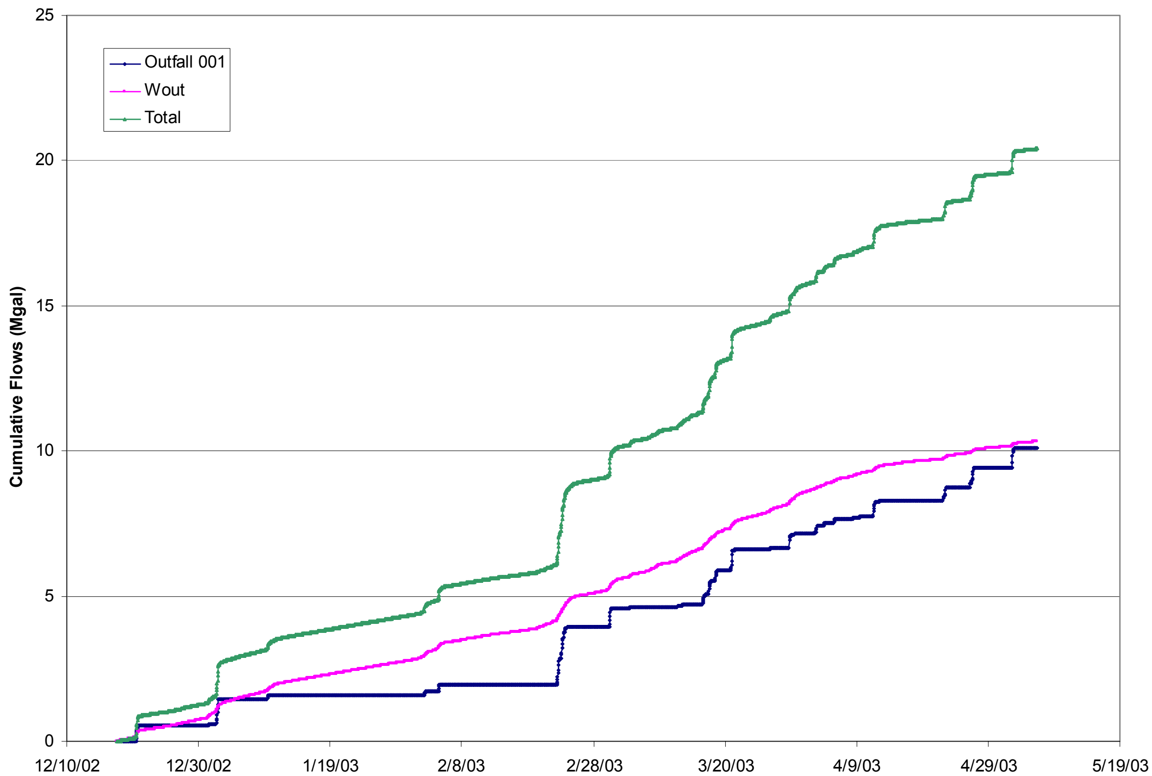


Figure 3-8. Estimated Cumulative Discharge Curves from Outfall 001 and Wetland Outflow

3.6.4 Residuals Handling

There are no residuals being generated by the SSF CTW system and none anticipated in within the normal life of the project.

3.6.5 Operating Parameters for the Technology

The SSF CTW system functions continuously and is passive. Minimal human intervention is required for operation. All storm events are intercepted and conveyed to the CTW site via the existing storm sewer. Normal flows are passively diverted to the O/W separator. High flows in the storm sewer overtop a low wall and flow directly into Cooley Brook. Most of the flow from the O/W separator flow into the wetland inflow distribution box. Higher flows bypass the wetland and flow directly to Cooley Brook. All flows are by gravity and no pumping is required. There are no weirs that require adjustment; however, visual inspection to insure that flows are diverted as desired is beneficial for operations. Monitoring is the only other requirement for system operation. Typical operator time for this system is estimated as about 1 hour per week. Electrical requirements associated with the demonstration project included the LAR Quick-TOC® continuous water and process online analyzing system, phone line, and heating in the equipment storage shed.

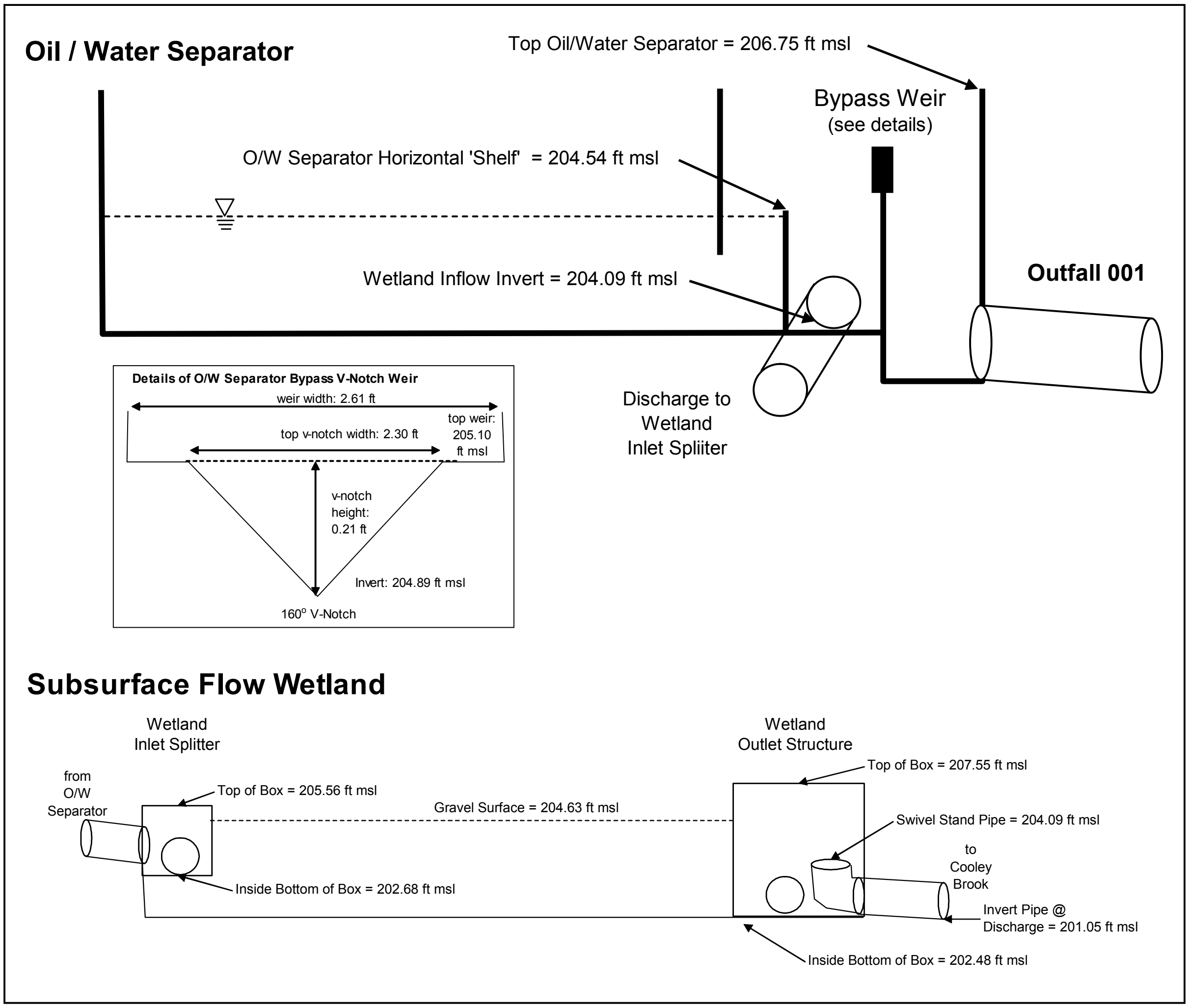


Figure 3-9. Hydraulic Profile of the Horizontal Subsurface Flow CTW at the Westover Air Force Reserve Base, Chicopee, MA

Figure 3-9 illustrates a hydraulic profile of the CTW as well as elevation details for the O/W Separator and wetland structures. The system was designed for an event mean flow of 100,000 gpd (69 gpm) with peak loadings approaching 400,000 gpd (278 gpm). Because of highly permeable, sandy soils at the site, a 30-mil PVC liner was placed between the wetland and surrounding soils. Approximately 2 feet of 1 ½ inch gravel media was placed on the liner for the CTW system base and a 3-inch layer of ¾-inch gravel was placed on the surface for a planting medium. The system is completely passive and operates under gravity flow, a design feature established since a 4-foot elevation change exists across the site as the elevation changes from 206.0 to 202.0 ft above mean seal level.

Figure 3-10. Outlet V-Notch Weir in the Oil/Water Separator

A 160^{o} V-notch weir was installed at the outlet of the O/W separator to accurately measure flow data discharging to Cooley Brook (Figure 3-10). Flow was

calculated using the following weir equations (Equations 4 through 6) and stage data from a pressure transducer installed upstream of the weir.

$$Q_T = Q_1 + Q_2 \quad [4]$$

$$Q_1 = 4.28\ C\ \tan(\text{Ø}/2)\ (H + k)^{5/2} \quad [5]$$

$$Q_2 = 3.33\ (L - 0.2\ H)\ H^{3/2} \quad [6]$$

Where:

Q_T = total flow (cfs)
Q_1 = flow over V-notch (cfs) (V-notch max H = 0.19 ft)
Q_2 = flow over rectangular weir with end contractions (cfs)
C = effective discharge coefficient ($C = 0.607165052 - 0.000874466963\ \text{Ø} + 6.10393334\times10^{-6}\ \text{Ø}^2$)
Ø = notch angle in degrees (180^{o})
k = Head correction Factor (ft) ($k = 0.0144902648 - 0.00033955535\ \text{Ø} + 3.29819003\times10^{-6}\ \text{Ø}^2 - 1.06215442\times10^{-8}\ \text{Ø}^3$)
H = head over v-notch invert (ft)
L = length of weir crest (ft)

3.6.6 Experimental Design

Figure 3-11 illustrates the surface water sampling stations for the SSF CTW Technology Demonstration project. The four surface water quality stations include:

- Oil/Water Separator Inflow (OWin)
- Oil/Water Separator Outflow (Outfall 001)
- Wetland Inflow (Win)
- Wetland Outflow (Wout)

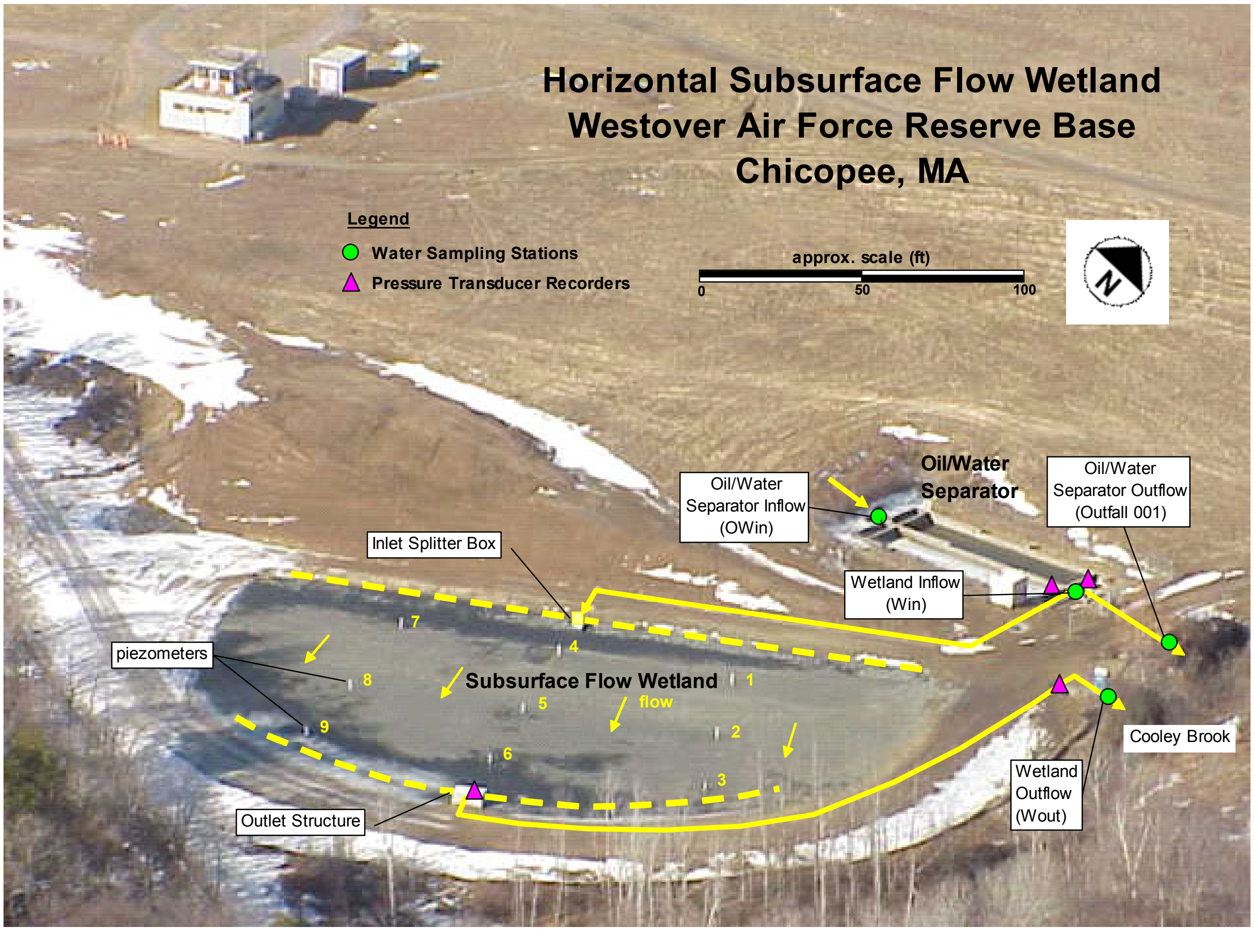


Figure 3-11. Aerial Photograph of the Horizontal Subsurface Flow Wetland at the Westover Air Force Reserve Base, Chicopee, MA

Table 3-4 summarizes the sampling activities at these stations and their sampling frequency.

Table 3-4. Monitoring Stations and Sampling Frequency

Station	Flow	Field Parameters[1]	Surface Water Parameters
Oil/Water Separator Inlet	---	---	O
Oil/Water Separator Outlet	SC	SC	M
Wetland Inlet	SC	SC	M, SC
Wetland Outlet	SC	SC	M, SC

SC = semi-continuous; flow measurement using stage vs. discharge relationship

O = monthly or other frequency

M = monthly

[1] include temperature, pH, Eh, turbidity, and conductivity

Semi-continuous water quality monitoring of pH, Eh, dissolved oxygen, temperature, conductivity, and turbidity were conduced in the O/W Separator and Wetland Outflow. In addition to the water quality monitoring, water levels were continuously measured at these two stations using pressure transducer data loggers. Water levels were used to estimate flow with weir equations. Flow measurements were used in the calculation of pollutant loads entering and exiting the constructed wetland and bypassing via Outfall 001. Westover ARB weather station records were used to estimate daily precipitation at the project site.

Surface water grab samples were collected at least monthly during the baseline period at Outfall 001. These samples were analyzed primarily for BOD, COD, and TOC. Total phosphorus, total kjeldahl nitrogen, nitrate+nitrite nitrogen, oil and grease (O&G), propylene glycol, and ADF additive constituents of concern.

Water samples during the experiment were collected from the two surface water monitoring stations (Win and Wout, illustrated in Figure 3-11). Both grab samples and continuous surface water sampling were conducted during the 2002-2003 de-icing season. These samples were analyzed primarily for BOD and COD. TC concentrations in the O/W separator and wetland outflow were measured continuously using a LAR Quick-TOC® continuous water and process online analyzing system.

3.6.7 Demobilization

The SSF CTW system is fully operational and provides benefits to Westover ARB's environmental compliance. For this reason it will not be dismantled following this demonstration operations period.

3.7 Selection of Analytical/Testing Methods

The analytical methods used were standard EPA Methods (or equivalent)[38,39] for all but the ADF additives. Table 3-5 provides a more detailed breakdown of the baseline and experiment sampling efforts, including analytical methods. The University of Colorado (UC), Boulder performed analytical procedures for the additives of concern. Since no standard method exists for many of the additives, UC Boulder used a gas chromatograph technique developed at the university. The analytical laboratory at Western Washington University (WWU) is also capable of accurate analysis of ADF additives.

3.8 Selection of Analytical/Testing Laboratory

Two types of analytical laboratories were necessary for this demonstration project. The laboratory at the University of Colorado, Boulder was used for the analysis of the additive components contained in ADFs (e.g. 4-MeBT), and propylene glycol analysis. Analysis for this and other ADF additive compounds is an expertise that can only be performed at select laboratories properly setup to do so. For analysis of more routine analytes, such as for nutrients, samples were sent to Spectrum Analytical and Con-Test Analytical, locally EPA certified labs.

Table 3-5. Surface Water Sampling, Analysis Parameters and Methods

Parameter	Analytical Method	Analytical Lab [6]	Monitoring Baseline	Monitoring Experiment
BOD_5	405.1 [1], 5210B [2]	CT / SA	X	X
COD	410.1 et al. [1], 5220B+C or D [2]	CT / SA	X	X
Propylene Glycol	8015M [5]	UC / CT / SA	X	X
ADF additives	[3]	UC	X	X
TOC	415.1/415.2 [1], 5310B [2]	CT / SA	X	
TSS	160.2 [1], 2540C [2]	CT	X	
Nitrate/Nitrite	353 Series [1], 4500 Series [2]	CT	X	
Kjeldahl Nitrogen	351 Series [1], 4500 Series [2]	CT	X	
Total Phosphorus	365 Series [1], 4500 Series [2]	CT	X	
Oil & Grease	413 Series [1], 5520 Series [2]	CT	X	
VOCs	624 [4], 6210 [2]	CT	X	
SVOCs (PAHs)	625 [4], 6410 [2]	CT	X	
Metals (15)	200.7 [1]	CT	X	

[1] Method reference from "Methods for Chemical Analysis of Water and Wastes", USEPA, EPA 600/4-79-020, Revised March 1983.
[2] Method reference from "Standard Methods for the Examination of Water and Wastewater", AWWA-WPCF-APHA, 17th Edition, 1989.
[3] Method does not exist. WWU and U. Colorado protocols to be used.
[4] Method reference from "Test Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater," EPA 600/4-82-057.
[5] Method from "Test Methods for Evaluating Soled Waste, Physical/Chemical Methods", USEPA , SW-846.
[6] CT = Con-Test; SA = Spectrum Analytical; UC = University of Colorado

4. Performance Assessment

4.1 Performance Criteria

The fundamental objective of the proposed project was to demonstrate that SSF constructed treatment wetlands can be used as a cost-effective method for mitigating the environmental and mission impacts of aircraft deicing operations. There are five primary and five secondary performance objectives of the CTW Technology Demonstration Project identified in the final demonstration plan [36] (Table 4-1). Each project objective consisted of a performance criterion and a corresponding performance expectation or metric.

Table 4-1. Performance Criteria for the CTW Technology Demonstration Project

No.	Performance Criterion	Description	Primary or Secondary	Type
1	Reduced cost	Reduction in annual or annualized compliance cost	Primary	Quantitative
2	Slug load treatment	Performance when $[BOD_5]$Influent > 500 mg/l	Primary	Quantitative
3	NPDES permit compliance[1]	Below $[BOD_5]$Effluent limit (monthly mean)	Primary	Quantitative
4	Readiness	Crew/deicing logistics and flight scheduling	Primary	Qualitative
5	Land use	Compatibility with surrounding land uses.	Primary	Qualitative
6	Wetland Health	Vegetation cover. Normal growth.	Secondary	Quantitative
7	Maintenance	Type, frequency, and labor requirements	Secondary	Quantitative
8	Reliability	Sensitivity to interruptions or cold	Secondary	Qualitative
9	NPS Removal	Reduction of NPS contaminants	Secondary	Quantitative
10	Toxicity Reduction	Reduction in whole effluent toxicity	Secondary	Quantitative

[1] Westover ARB currently has an individual permit issued by EPA's Region I (NPDES Permit No. MA0005444) to discharge storm water at Outfalls 001 and 002. The remaining outfalls at the Base (Outfalls 003 through 009) are permitted by EPA Region I for coverage under the multi-sector general permit published in the September 29, 1995 Federal Register (60 FR 50803).

4.2 Performance Confirmation Methods

The following section describes the procedures used in analyzing the performance of the SSF CTW Technology Demonstration Project for flow attenuation and removal of BOD in the waste stream. Table 4-2 provides a summary of the performance confirmation provided by the operational monitoring data. Detailed performance objectives and assessment methods are presented in the Project Demonstration Plan [36].

Table 4-2. Expected Performance and Performance Confirmation Methods

No.	Performance Criterion	Expected Performance	Performance Confirmation Method (Metric)	Actual Performance (post demo)	Criterion Met
1	Reduced cost	(a) Annual cost < \$2500 or (b) annualized cost < \$1 lb BOD_5/yr, as appropriate	(a) annual cost calculation or (b) calculation of annualized cost per lb BOD_5 removed per year, as appropriate	Non-demonstration costs are \$3,000 per year.	Y
2	Slug load treatment	> 80 % BOD_5 reduction	Percent reduction calculation	All events: -47 to 81 %; average = 44 %	N
3	NPDES permit compliance	$[BOD_5]$Effluent < 30 mg/l	Calculation of flow-weighted, monthly-mean $[BOD_5]$Effluent	Monthly mean range: 56 – 1,879 mg/L	N
4	Readiness	Improved deicing logistics and flight scheduling	Observations by team members and base personnel.	No data re: flight scheduling; Minimal operation and maintenance requirements	Y
5	Land use	No BASH impacts; no odors	Observations by team members and base personnel.	One pair killdeer nesting on site; no odor problems noted	Y
6	Wetland Health	Vegetation cover w/in +/- 20 % of expected values. Normal growth.	Calculation of cover after one year from startup. Observation of growth.	Estimated 90 % survival	Y
7	Maintenance	No more burdensome than baseline technology.	Calculation of the cost and frequency of each maintenance item.	1.5 hrs per week	Y
8	Reliability	Consistent performance, no upset conditions.	Observation of performance.	No upset conditions	Y
9	NPS Removal	Removal rates w/in one standard deviation of available stormwater wetland technology	Calculation of removal rates and comparison to wetland technology using appropriate comparison basis.	No NPS pollutants reported during experimental period	---
10	Toxicity Reduction	A noticeable reduction in toxicity from influent to effluent samples.	Comparison of WET test results.	No operational monitoring data	---

The fundamental objective of the demonstration project is to demonstrate that SSF CTW can be used as a cost-effective method for mitigating the environmental and mission impacts of aircraft deicing operations. The annualized cost is a quantitative performance metric and was estimated from operation and maintenance and analytical testing costs. Operation and maintenance costs did not include any costs associated only with the

demonstration that would not be incurred in full scale installations (e.g. utilities and monitoring equipment).

Propylene glycol is the principal chemical of concern for oxygen demand in ADFs. Propylene glycol has a high BOD_5 that is exerted when it is released at elevated concentrations in surface waters. Therefore, BOD_5 was used as the measurement for the primary performance objective of slug load treatment of ADFs. BOD_5 slug load reduction was estimated using the percent reduction calculation between peak events. An example for the December 8 – 15, 2002 event (Event A on Figure 4-6) is presented below.

$$\text{Percent reduction} = (\text{Cin} - \text{Cout}) / \text{Cin} \times 100 \qquad [7]$$

Where,

Cin = peak inflow concentration (mg/L); 1,508 mg/L

Cout = peak outflow concentration (mg/L); 775 mg/L

Percent reduction = 48.6%

The BOD_5 NPDES permit compliance primary performance criterion of less than 30 mg/L (monthly mean) discharge from the CTW Demonstration Project was an inappropriate criterion as it was for an individual permit on an outfall and now Outfall 001 is under the multi-sector permit. Therefore the expected performance metric is irrelevant as Outfall 001 is in compliance with the NPDES permit requirements.

Impacts to the Westover mission were considered a primary performance criterion for the CTW Demonstration Project. Mission and operational aspects evaluated include improved deicing logistics, ease of operation, and flight scheduling. The performance confirmation method will be through observations by team members and base personnel reports.

The goal of the land use compatibility objective was not to create or increase any bird-strike hazards (BASH) at Westover ARB and to not produce objectionable odors. The performance confirmation method will be through observations by team members and base personnel reports.

Survivability or wetland health is a secondary performance objective. Wetland planting was conducted in June 2002 and the percent survival was estimated by team members approximately 1 year later to determine if vegetation cover is within 20 percent of expected growth.

Another secondary performance objective for this demonstration is the maintenance requirements and impact of base operations as a result of the CTW. The performance confirmation method is the calculation of the cost and frequency of operator training and maintenance.

Reliability of the CTW is a secondary performance objective for this demonstration. Reliability would include CTW sensitivity to interruptions or cold. The performance confirmation method is confirmation that the CTW operated as designed throughout the experiment period.

Due to budget constraints, ecological effluent toxicity sampling and NPS pollutant monitoring was not conducted at the CTW Demonstration Project site.

4.3 Data Analysis Interpretation and Evaluation

4.3.1. Flow Estimates

Water levels in the O/W separator and wetland outlet box were used to estimate flow using weir equations. These estimated flow measurements were used in the calculation of pollutant mass loads entering and exiting the constructed wetland and bypassing via Outfall 001.

Wetland bypass flows over the 160^o V-notch weir in the O/W separator (via Outfall 001) were estimated using Equations 4 through 6 described above.

Water elevation and outflows in SSF CTW Technology Demonstration Project are controlled via a rotating 1-foot diameter 90^o elbow attached to a corrugated plastic pipe within the concrete wetland outlet box. This outlet box interconnects the CTW outlet drain pipes with the discharge pipe to Cooley Brook. A pressure transducer water level recorder (Infinities USA, Inc.) was installed in this outlet box to monitor water levels. Currently, we do not have a standard weir or weir equation to estimate outflows from the CTW. The methods used to estimate outflows are described below.

The relationship between outflow and water levels in the concrete outlet box were estimated using actual flow measurements collected on 5/6/03. Flow measurements were estimated using a 5-gallon bucket and stopwatch at the discharge point to Cooley Brook. The range of outflows and depths were from 22.9 to 48.0 gpm and 204.19 to 204.24 ft msl, respectively. These measurements resulted in the following empirical equation:

$$Q = 476.42 \times H - 97260 \qquad R^2 = 0.89 \qquad [8]$$

Where,

Q = outflow (gpm)

H = water elevation in outlet box (ft msl)

Due to the narrow range of water depths and flows used in Equation 8, another method was also evaluated to estimate flows. Several standard weir equations, including rectangular and v-notch weirs, were used to establish the relationship between surface water cross-sectional area through the weir and outflow at a range of water depths. For example, the relationship for a 90^o V-notch weir results in the following equation (Figure 4-1):

$$Q = 2.3934 \times A^{1.2213} \qquad R^2=1.00 \qquad [9]$$

Where,

Q = flow (cfs)

A = cross-sectional area (ft^2)

The cross-sectional area (cord) through the 1-foot outlet pipe in the SSF CTW was calculated for water elevations measured in the outlet box. These cross-sectional areas were used to estimate outflows from the CTW. The 90^o V-notch area vs. flow relationship (Equation 8) resulted in the best fit in comparison to the actual measured outflows (R^2 = 0.91). Equation 9 was used subsequently to estimate outflow for the SSF CTW Technology Demonstration Project. Wetland inflows were assumed to equal outflows since the system

was lined and measured event mean hydraulic loads during events (11 to 32 cm/d) were typically much greater than the net effects of precipitation and evapotranspiration.

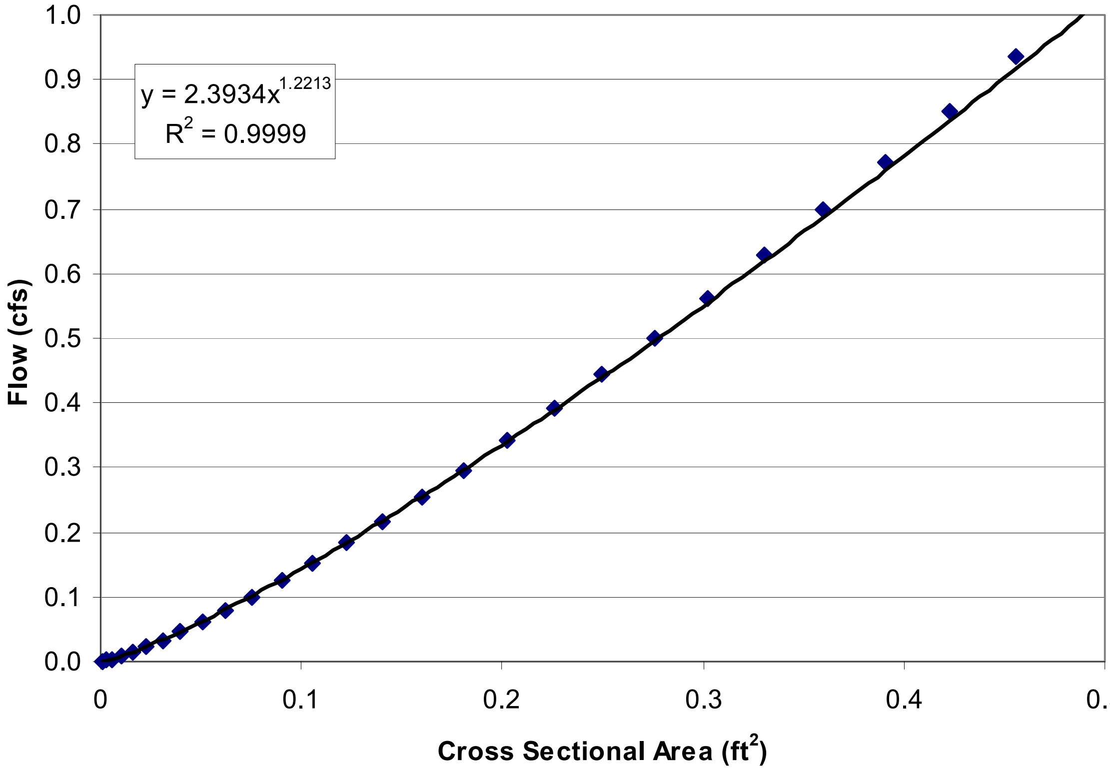


Figure 4-1. Relationship between Surface Water Cross Sectional Area and Flow for a 90º V-Notch Weir

4.3.2. BOD and COD Estimates

A LAR Quick-TOC® continuous water and process online analyzing system was installed during the demonstration project to report continuous TC concentration in the O/W Separator (Wetland Inflow) and Wetland Outflow. In order to reduce sampling and analytical costs, the LAR TC measurements were used to estimate BOD concentrations entering and exiting the wetland, therefore estimating the wetlands BOD removal efficiency. The correlation between the LAR TC measurements and BOD samples collected in the SSF CTW Technology Demonstration Project resulted in an R^2 of 0.75 and an estimated BOD/TC ratio of 0.65 (Figure 4-2). Correlations between BOD and COD were established using baseline monitoring data (Period of Record: 2/1/94 - 4/7/03) and resulted in a median BOD/COD ratio of 0.40.

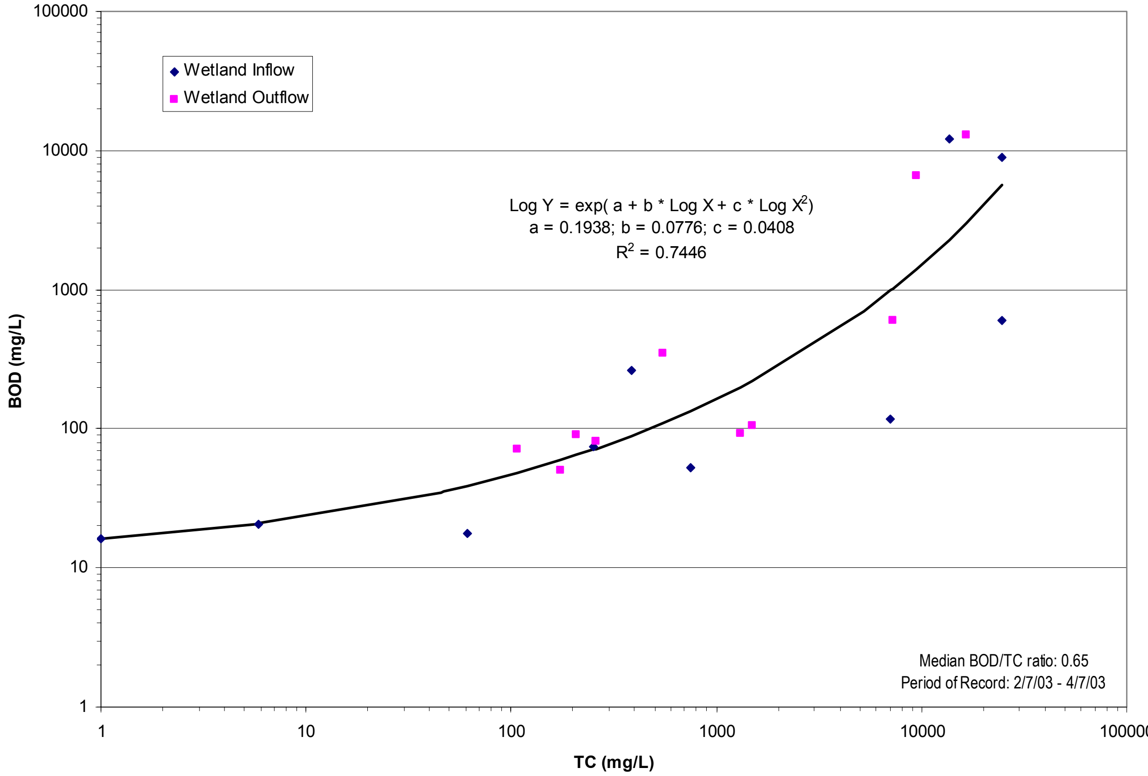


Figure 4-2. Correlation between the LAR TC Measurements and BOD Samples Collected in the SSF CTW Technology Demonstration Project

4.3.3 Pollutant Mass Balances

Pollutant mass balances were determined by multiplying flows and concentrations. Inflow loads were based on hourly inflow estimates and estimated BOD concentrations as described above. Outflow loads were calculated from outflow flow and concentration estimates. Flow-weighted mean concentrations were prepared by totalizing loads over a given time period and dividing by the total cumulative flow for that period. Pollutant removal rates were calculated as the difference between the inflow and outflow loads.

Pollutant load reduction was determined for three specific deicing/storm flow events that occurred during the experimental period (February 8 – 24, 2003; March 1 – 3, 2003; and April 5 – 13, 2003). Complete data records were available for each of these events. Concentration reductions were also calculated for an additional event (December 9 – 12, 2002).

4.3.4 Water Levels

Figure 4-3 provides a time-series plot of the estimated O/W separator and CTW water levels during the experimental period from December 2002 through May 2003. This figure also shows the fixed levels for the wetland inlet invert, the O/W separator overflow weir, the

wetland bed surface, and the wetland outlet weir invert. The average water level in the O/W separator during this period was 204.47 ft msl and the average water level in the CTW was 204.24 ft msl.

Data in this figure indicate that there were at least 24 precipitation events during this experimental period. Not all of these events resulted in measurable releases of ADF to the O/W separator and CTW. Water levels in the O/W separator overtopped the internal weir at least 26 times, resulting in inflows to the CTW during those periods. Water levels overtopped the overflow weir in the O/W separator at least 26 times during this period, resulting in bypassed flows directly to Cooley Brook.

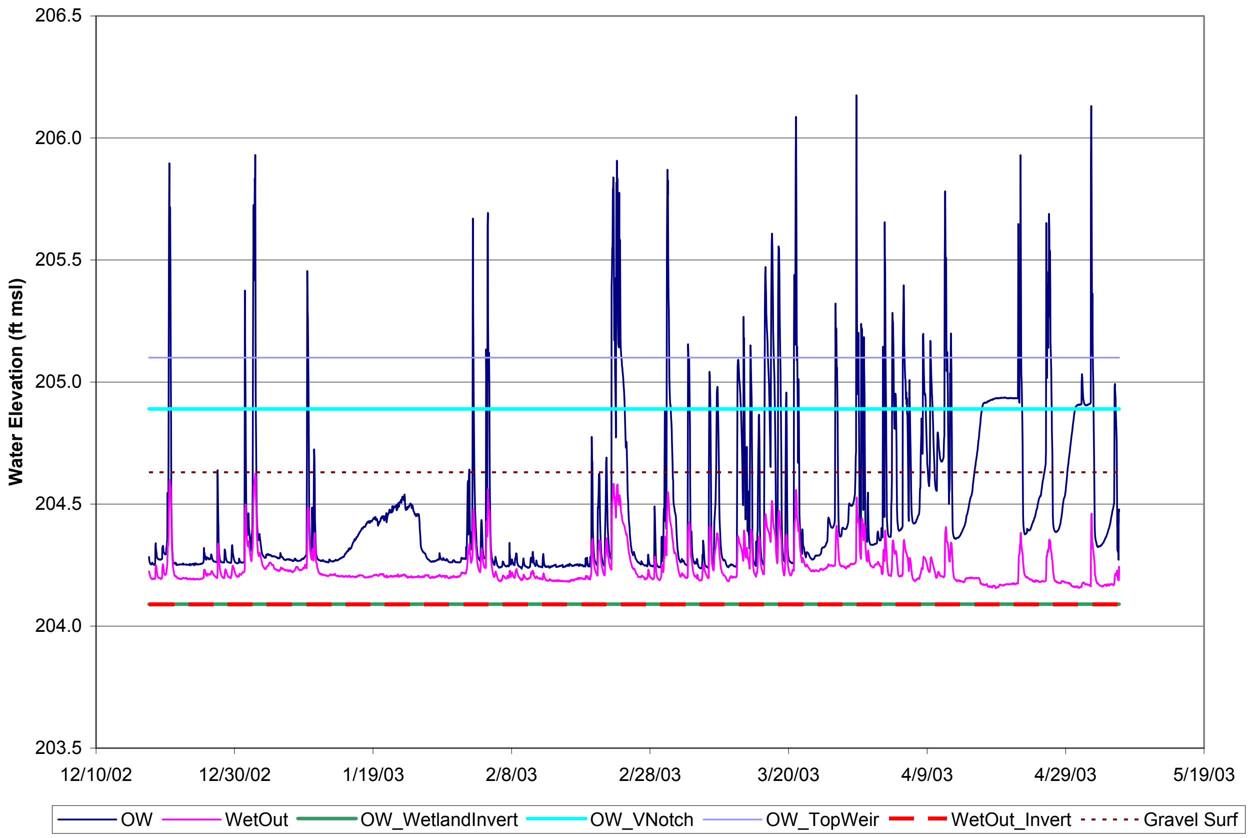


Figure 4-3. Water Elevations Used to Estimate Bypass and Wetland Flows

4.3.5 Flows

A time-series of estimated CTW outflows is illustrated in Figure 4-4. Bypass flows from the O/W separator are also shown in Figure 4-4. Total flow from the O/W separator during the experimental period from December 2002 through May 2003 was 20.43 million gallons. Of this total flow about 51 percent was routed through the CTW and 49 percent was bypassed directly to Cooley Brook without additional treatment.

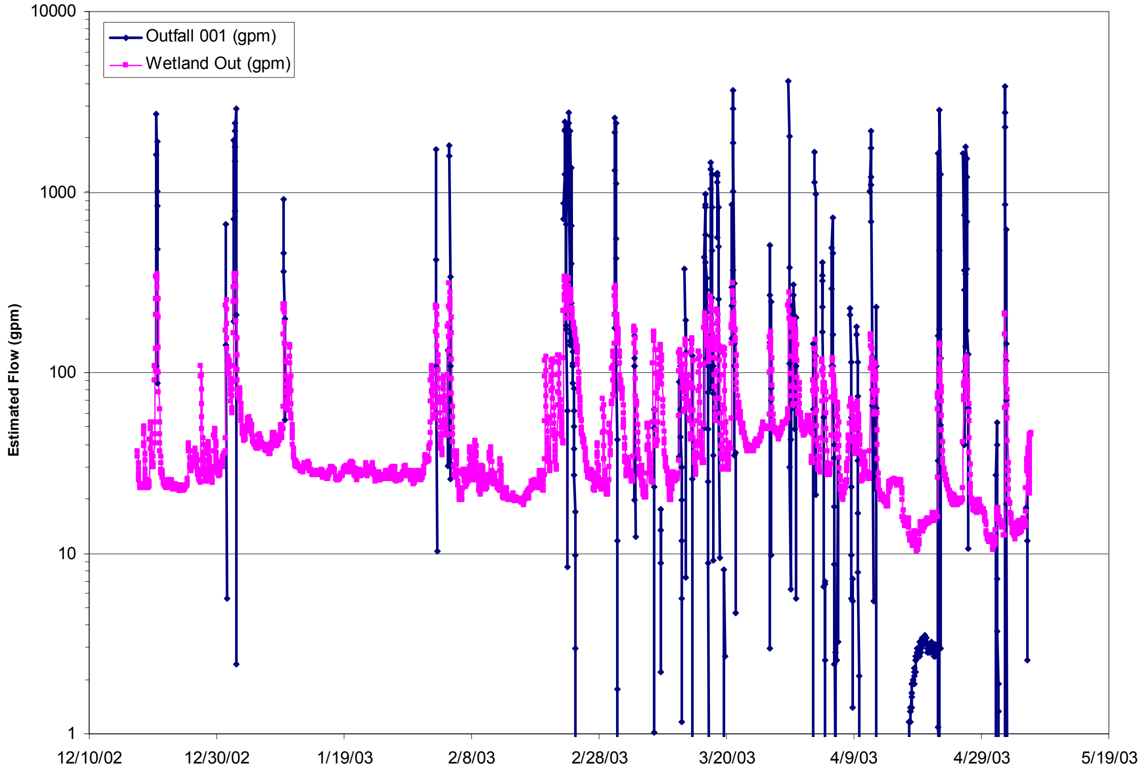


Figure 4-4. Estimated Bypass (Outfall 001) and Wetland Outflows

4.3.6 BOD Concentration and Load Reductions

Period-of-record data for total carbon (TC) from the LAR and ADF usage records are plotted in Figure 4-5. There were 38 recorded deicing events in this watershed during the experimental period. Most of these events resulted in immediate TC concentration responses downstream at Outfall 001. A total of 51,355 gallons of ADF was applied in this basin during this period-of record.

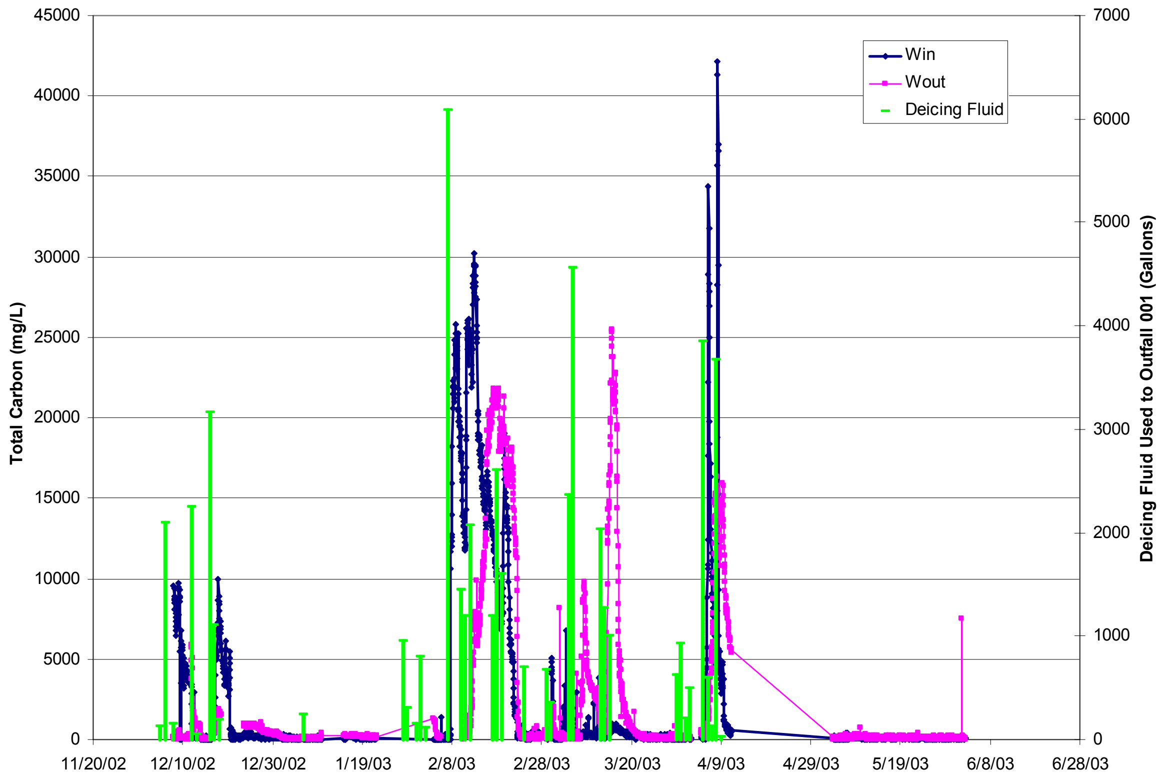


Figure 4-5. Time Series Plot of LAR TC and ADF Usage During the 2002-2003 Deicing Season

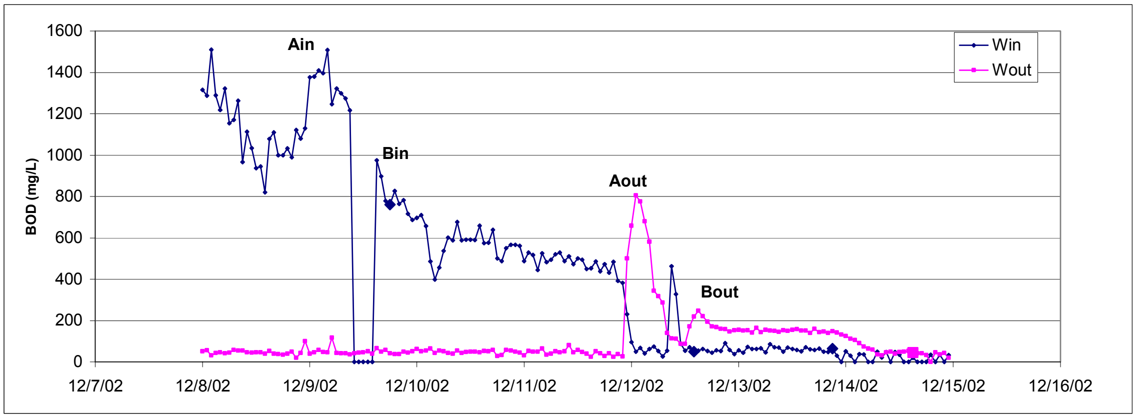
Four specific events were analyzed for either estimated BOD concentration or load reductions. Summaries are provided below of the detailed analysis for each of these storm events. Table 4-3 provides a summary of these results.

Figure 4-6 summarizes the data from the first recorded event (December 8–14, 2002). This event occurred before the flow measurement system was fully in place and therefore it only includes concentration estimates. Average estimated inflow and outflow BOD concentrations for the CTW during this event were 455 and 100 mg/L, for an estimated concentration reduction of 78 percent. These data indicate that the SSF CTW significantly lowered the average BOD concentration entering Cooley Brook compared to the direct outflow from the O/W separator to the brook.

Table 4-3. Summary of Results from the Westover ARB SSF CTW Demonstration Project Performance, 2002 – 2003 Deicing Season

Parameter	Dec 2002	Feb 2003	Mar 2003	Apr 2003
BOD Average				
CTW Inflow (mg/L)	455	2,644	165	1,228
CTW Outflow (mg/L)	100	1,667	112	1,090
CTW Removed (mg/L)	355	977	52	137
CTW Removed (%)	78.0	36.9	31.7	11.2
Bypass (mg/L)	---	58	81	790
BOD Flow-Weighted Mean				
CTW Inflow (mg/L)	---	1,434	129	1,183
CTW Outflow (mg/L)	---	1,247	133	937
CTW Removed (mg/L)	---	186	-4	246
CTW Removed (%)	---	13.0	-3.0	20.8
Bypass (mg/L)	---	58	75	319
Combined Outfall 001 (mg/L)		524	94	581
BOD Mass Removals				
CTW Inflow (kg/d)	---	414	109	334
CTW Outflow (kg/d)	---	360	113	264
CTW Removed (kg/d)	---	54	-3	69
CTW Removed (%)	---	13.0	-3.0	20.8
Bypass (kg/d)	---	26	130	122
Combined Outfall 001 (kg/d)	---	386	243	386
CTW Inflow (kg/ha/d)	---	1,705	450	1,374
CTW Outflow (kg/ha/d)	---	1,484	464	1,088
CTW Removed (kg/ha/d)	---	221	-13	286
Removed (%)	---	13.0	-3.0	20.8
Wetland / Bypass Flows				
Average Wetland Flow (gpm)	---	53	151	51
Total Wetland Flow (Mgal)	---	1.29	0.33	0.59
Average Bypass Flow (gpm)	---	82	310	70
Total Bypass Flow (Mgal)	---	2.01	0.67	0.80
Total Flow (Mgal)	---	3.31	0.99	1.40
Treated Flow (%)	---	39.1	32.8	42.5
Average Temperature (F)	27.1	19.5	26.7	36.4
Average Precipitation (in/d)	0.19	0.22	0.25	0.15
Average HLR (in/d)	---	4.7	13.3	4.5
Average Residence Time (d)	3.0	3.9	0.5	1.6

Note(s):
Wetland Area (ha) = 0.243
Wetland Flows are based on Wetland Outflow Measurements
Dec 2002 = 12/8/02 - 12/14/02 (7 days)
Feb 2003 = 2/7/03 - 2/23/03 (17 days)
Mar 2003 = 3/1/03 - 3/3/03 (1.5 days)
Apr 2003 = 4/5/03 - 4/12/03 (8 days)



Event	Time			BOD (mg/L)			
	In	Out	# Days	In	Out	Diff	%
A	12/9/2002 4:00	12/12/2002 2:00	2.9	1,508	775	733	48.6
B	12/9/2002 15:00	12/12/2002 15:00	3.0	974	247	726	74.6

Start:	12/8/2002 0:00
End:	12/14/2002 23:00
# days:	6.96
# hrs:	167

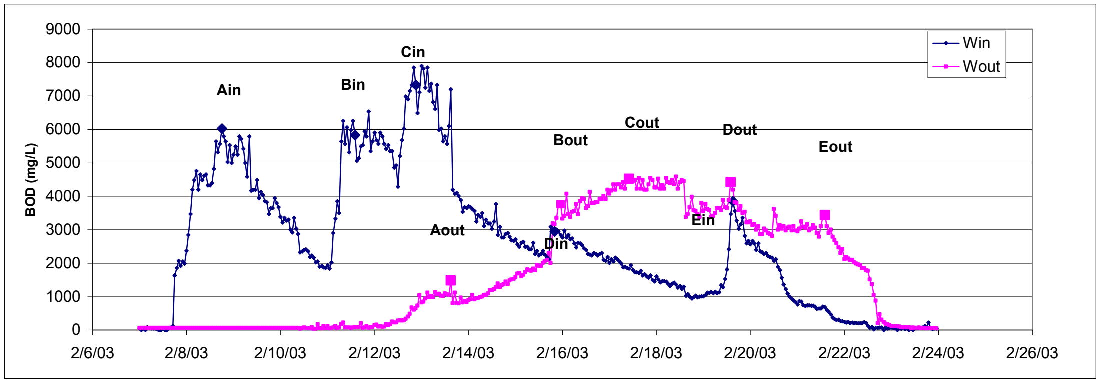
Average (mg/L)			
BOD_in	BOD_out	Difference	%
455	100	355	78.0

Average	
Precipitation (in/d)	Temp (F)
0.19	27.1

Figure 4-6. Summary from the First Recorded Event (December 8 – 15, 2002)

Figure 4-7 summarizes the data from the second recorded event (February 7–23, 2003). This event includes BOD concentration, flow, and BOD mass estimates for at least five closely spaced flow events. Average estimated inflow and outflow BOD concentrations for the CTW during this entire event were 2,644 and 1,667 mg/L, for an average concentration reduction of 37 percent. Peak inflow and outflow concentrations were reduced from 3,000 to 7,330 mg/L at the inflow to 1,490 to 4,520 mg/L at the outflow, or by -47 to 75 percent.

The hydraulic residence time (HRT) is the time that water spends within the bed and is subject to pollutant removal processes. The apparent HRT in the bed estimated from the period of time between concentration peaks was from 1.9 to 4.9 days. Event mean flow through the CTW was 53 gpm for an average hydraulic loading rate (HLR) of 4.7 in/d. Recorded precipitation during this period averaged 0.22 in/d. Event flow-weighted mean concentrations for BOD were 1,434 and 1,247 mg/L at the CTW inflow and outflow, for an estimated mass reduction of 13 percent. The estimated inflow and outflow masses of BOD were 7,021 and 6,110 kg, for a net mass removal estimate of 911 kg or 221 kg/ha/d. The estimated mass of BOD going directly from the O/W separator overflow to Cooley Brook was 442 kg at a flow-weighted mean concentration of 58 mg/L. These data indicate that the SSF CTW significantly lowered the average BOD concentration and load entering Cooley Brook compared to the original system with no CTW in place. The CTW operated as designed with no recorded surface flow and no apparent freezing throughout this period of severe weather.



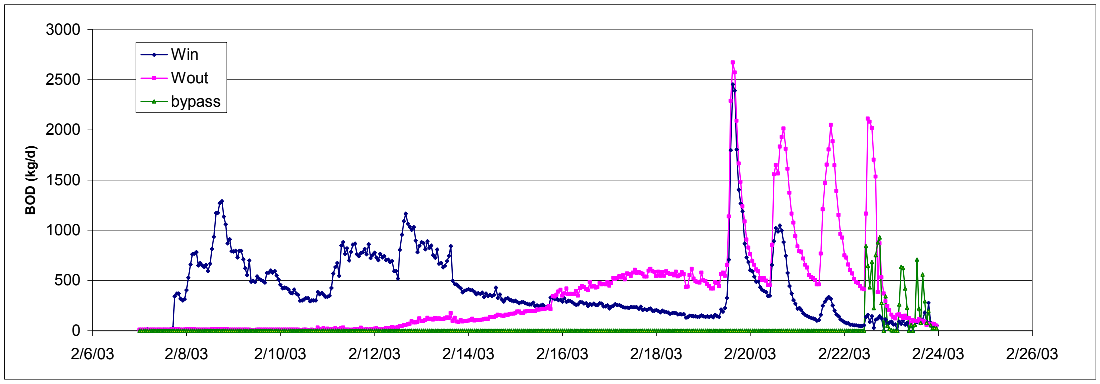
Event	Time			BOD (mg/L)			
	In	Out	# Days	In	Out	Diff	%
A	2/8/2003 18:00	2/13/2003 15:00	4.9	6,022	1,487	4,535	75.3
B	2/11/2003 14:00	2/15/2003 23:00	4.4	5,831	3,766	2,065	35.4
C	2/12/2003 21:00	2/17/2003 10:00	4.5	7,329	4,521	2,808	38.3
D	2/15/2003 21:00	2/19/2003 14:00	3.7	3,002	4,422	-1,420	-47.3
E	2/19/2003 16:00	2/21/2003 14:00	1.9	3,559	3,444	115	3.2

Start:	2/7/2003 0:00
End:	2/23/2003 23:00
# days:	16.96
# hrs:	407

Average		
HLR (in/d)	Precip (in/d)	Temp (F)
4.67	0.22	19.5

Parameter	Average mg/L	FWM mg/L	Mass kg	Mass kg/d	Average gpm	Total gallons
BOD_in	2,644	1,434	7,021	414	53	1,293,780
BOD_out	1,667	1,247	6,110	360	53	1,293,780
BOD_bypass	58	58	442	26	82	2,011,830

Mass Removed	
221	kg/ha/d
911	kg
13.0	%



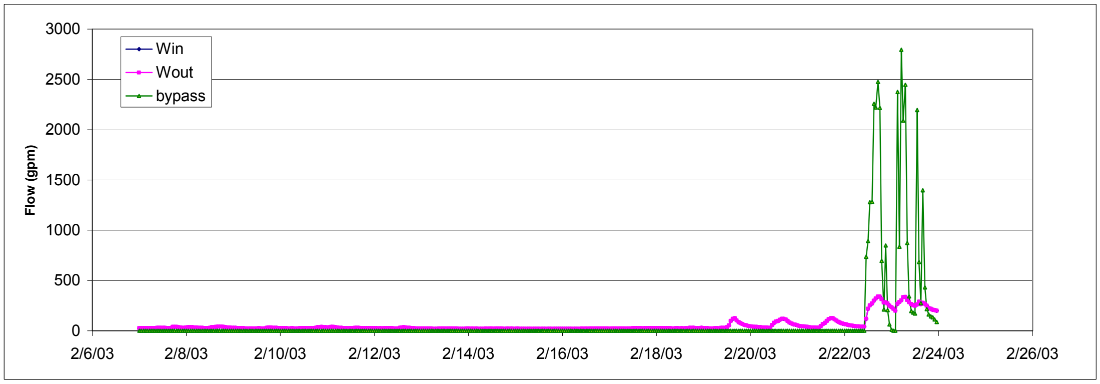
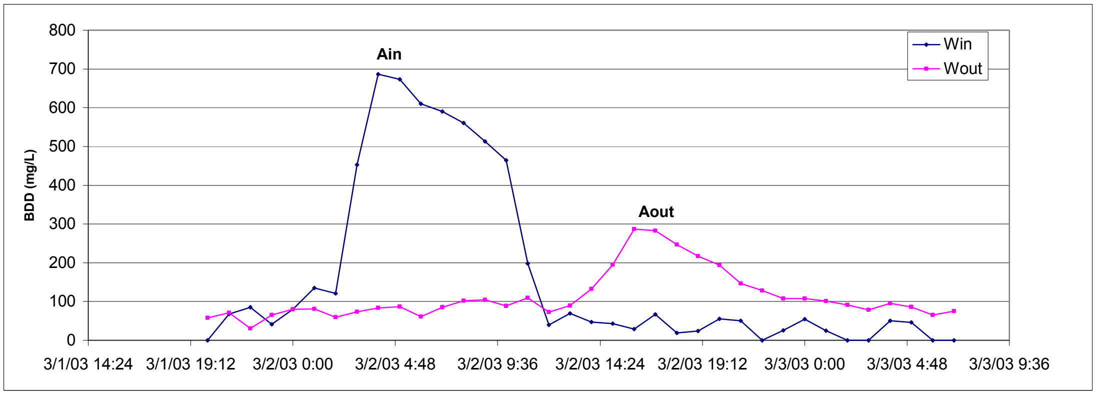


Figure 4-7. Summary from the Second Recorded Event (February 7 – 23, 2003)

Figure 4-8 summarizes the data from the third recorded event (March 1–3, 2003). This event includes BOD concentration, flow, and BOD mass estimates for at least five closely spaced flow events. Average estimated inflow and outflow BOD concentrations for the CTW during this entire event were 165 and 112 mg/L, for an average concentration reduction of 32 percent. Peak inflow and outflow concentrations were reduced from 686 to 287 mg/L or by 58 percent. The apparent hydraulic residence time (HRT) in the bed estimated from these concentration peaks was from 0.5 days. Event mean flow through the CTW was 151 gpm for an average HLR of 13.3 in/d. Recorded precipitation during this period averaged 0.25 in/d. Event flow-weighted mean concentrations for BOD were 129 and 133 mg/L at the CTW inflow and outflow. There was no BOD mass reduction estimated at these relatively low inlet BOD levels. The estimated inflow and outflow masses of BOD were 159 and 164 kg. The estimated mass of BOD going directly from the O/W separator overflow to Cooley Brook was 190 kg at a flow-weighted mean concentration of 75 mg/L. These data indicate that the SSF CTW did not measurably lower the average BOD concentration and load entering Cooley Brook during this event. However, peak and average concentrations of BOD entering Cooley Brook were significantly lowered by the system. The CTW operated as designed with no recorded surface flow and no apparent freezing throughout this period of severe weather.

Figure 4-9 summarizes the data from the fourth recorded event (April 5–12, 2003). This event includes BOD concentration, flow, and BOD mass estimates for at least five closely spaced flow events. Average estimated inflow and outflow BOD concentrations for the CTW during this entire event were1,228 and 1,090 mg/L, for an average concentration reduction of 11 percent. Peak inflow and outflow concentrations were reduced from 10,082 to 15,098 mg/L at the inflow to 2,818 to 2,949 mg/L at the outflow, or by 71 to 81 percent. The apparent hydraulic residence time (HRT) in the bed estimated from these concentration peaks was from 1.3 to 1.9 days. Event mean flow through the CTW was 51 gpm for an average hydraulic loading rate (HLR) of 4.5 in/d. Recorded precipitation during this period averaged 0.15 in/d. Event flow-weighted mean concentrations for BOD were 1,183 and 937 mg/L at the CTW inflow and outflow, for an estimated mass reduction of 21 percent. The estimated inflow and outflow masses of BOD were 2,655 and 2,103 kg, for a net mass removal estimate of 552 kg or 286 kg/ha/d. The estimated mass of BOD going directly from the O/W separator overflow to Cooley Brook was 969 kg at a flow-weighted mean concentration of 319 mg/L. These data indicate that the SSF CTW significantly lowered the average BOD concentration and load entering Cooley Brook compared to the original system with no CTW in place. The CTW operated as designed with no recorded surface flow and no apparent freezing throughout this period of severe weather.



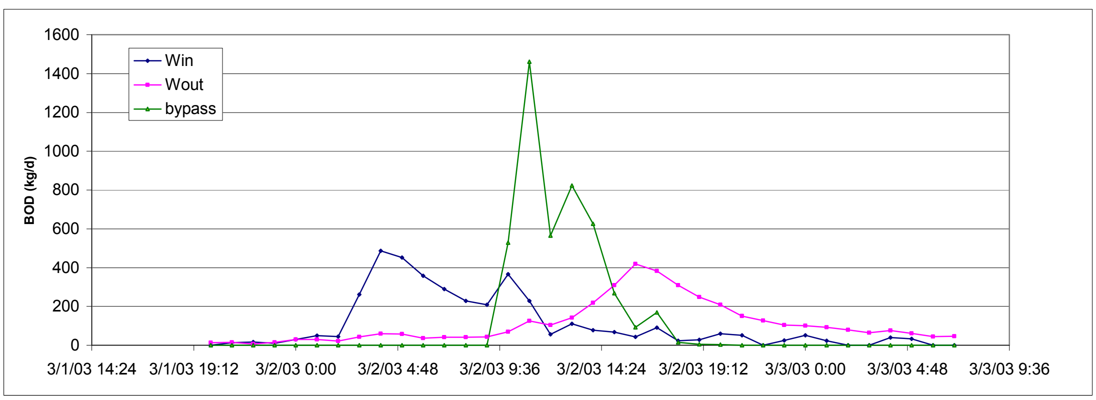
Event	Time			BOD (mg/L)			
	In	Out	# Days	In	Out	Diff	%
A	3/2/2003 4:00	3/2/2003 16:00	0.5	686	287	399	58.2

Start:	3/1/2003 20:00
End:	3/3/2003 7:00
# days:	1.46
# hrs:	35

Average		
HLR (in/d)	Precip (in/d)	Temp (F)
13.3	0.25	26.7

Parameter	Average mg/L	FWM mg/L	Mass		Average gpm	Total gallons
			kg	kg/d		
BOD_in	165	129	159	109	151	325,944
BOD_out	112	133	164	113	151	325,944
BOD_bypass	81	75	190	130	310	668,570

Mass Removed	
-13	kg/ha/d
-5	kg
-3.0	%



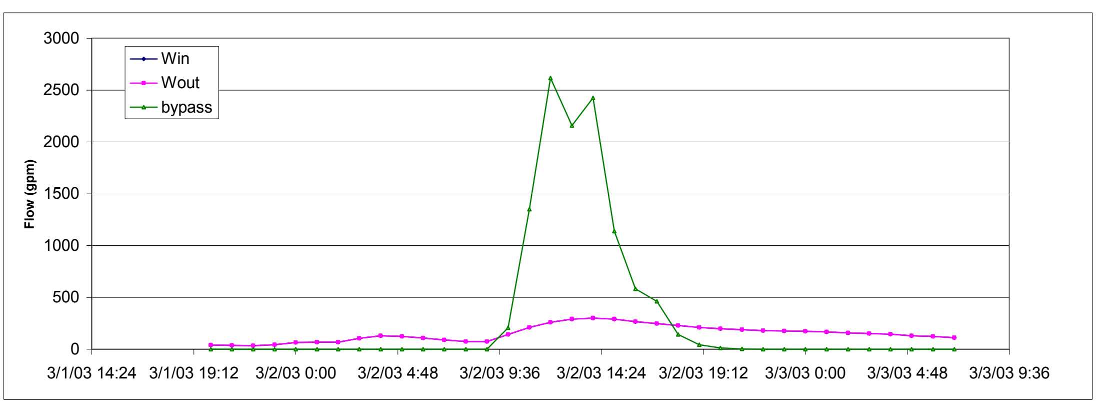
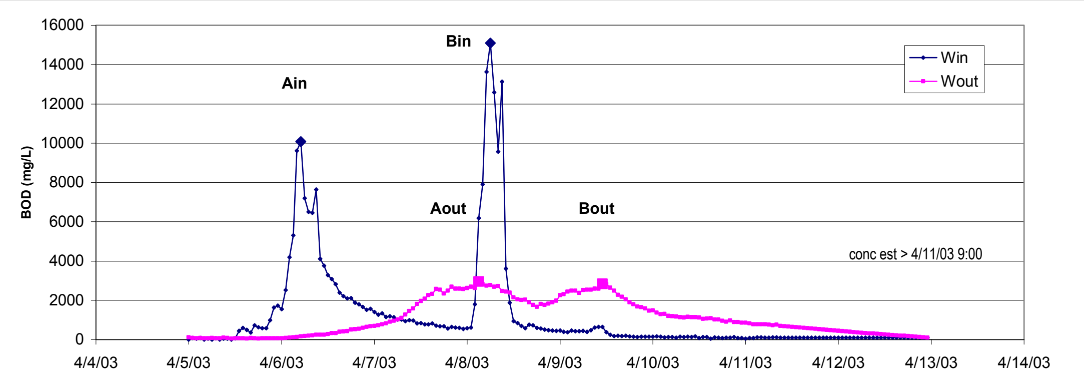


Figure 4-8. Summary from the Third Recorded Event (March 1 – 3, 2003)



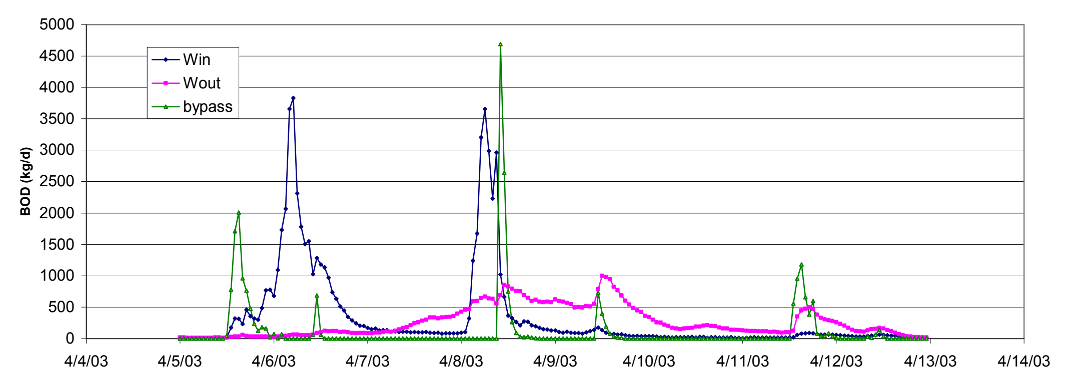
Event	Time			BOD (mg/L)			
	In	Out	# Days	In	Out	Diff	%
A	4/6/2003 5:00	4/8/2003 3:00	1.9	10,082	2,949	7,133	70.7
B	4/8/2003 6:00	4/9/2003 12:00	1.3	15,098	2,818	12,280	81.3

Start:	4/5/2003 0:00
End:	4/12/2003 23:00
# days:	7.96
# hrs:	191

Average		
HLR (in/d)	Precip (in/d)	Temp (F)
4.5	0.15	36.4

Parameter	Average mg/L	FWM mg/L	Mass kg	Mass kg/d	Average gpm	Total gallons
BOD_in	1,228	1,183	2,655	334	51	593,089
BOD_out	1,090	937	2,103	264	51	593,089
BOD_bypass	790	319	969	122	70	803,020

Mass Removed	
286	kg/ha/d
552	kg
20.8	%



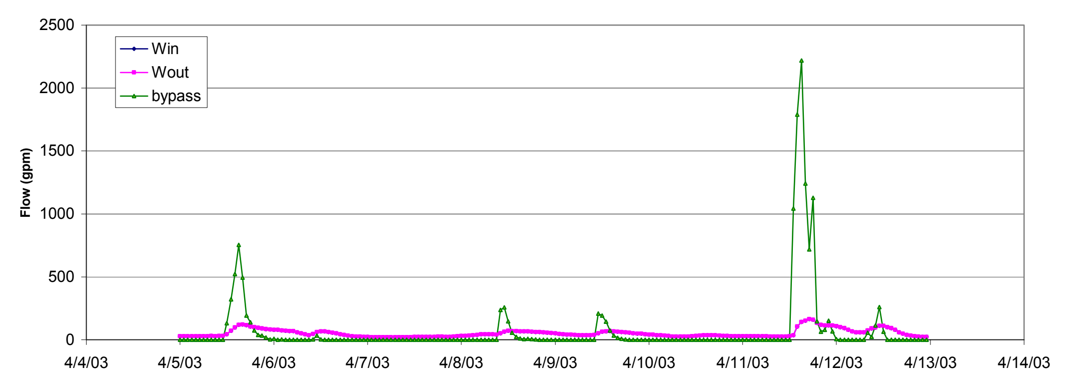


Figure 4-9. Summary from the Fourth Recorded Event (April 5 - 12, 2003)

4.3.7 Other Analytical Measurements

Table 4-4 summarizes other analytical measurements from surface water grab samples and the Hydrolab multi-parameter sonde installed in the O/W separator (Win) and wetland outflow (Wout) during this study. Peak concentrations of MeBT were reduced with travel through the CTW but there was no measurable change in the average concentration. Dissolved oxygen (DO) percent saturation and redox potential decreased with passage through the CTW while pH increased. There was a slight reduction in turbidity with passage of the stormwater through the CTW and a slight increase in water temperature.

Table 4-4. Summary of Analytical Results from the Westover ARB SSF CTW Demonstration Project Performance, 2002 - 2003

Parameter	Units	Statistics	Wetland Inflow	Wetland Outflow
BOD	mg/L	Average	2226	2094
		Max	12100	12900
		Min	16.2	50.8
COD	mg/L	Average	1883	1335
		Max	37900	23100
		Min	3	100
MeBT	mg/L	Average	0.68	0.72
		Max	20.93	4.77
		Min	0.02	0.02
DO	%	Average	52.2	47.7
		Max	103.9	69.8
		Min	8.8	8.8
pH	SU	Average	7.58	9.54
		Max	8.95	13.92
		Min	5.61	6.54
Redox	mV	Average	391	172
		Max	596	518
		Min	235	-272
Temp	C	Average	17.3	18.9
		Max	26.8	32.7
		Min	10.8	12.1
Turbidity	ntu	Average	5.22	4.61
		Max	10.7	7.06
		Min	0.88	1.16

Period of Record:

Grab samples (BOD, COD, MeBT): 2/20/02 - 4/7/03

Hydrolab Parameters: 6/6/02 - 7/2/02

4.3.8 CTW Vegetation Development

Growth of the common reed planted in the CTW in June 2002 was relatively slow during this first year post-construction. Although more than 90 percent of the plants survived, estimated plant cover in early May 2003 was less than 5 percent. Since plants contribute to the treatment process by supplying a constant supply of abundant reduced carbon, it is likely that the CTW was not at full maturity and treatment capacity during the period of this demonstration. Additional water quality and flow monitoring is recommended to assess performance changes in the CTW over a period of up to 5 years.

4.3.9 Wildlife Usage

One bird species was observed to use the SSF CTW during the period of this demonstration. This species was the killdeer and a pair nested in on the gravel surface during late spring 2003. This species is a common resident on Westover ARB and normally nests at higher elevations near the runway. Killdeer are not likely to nest within the CTW once vegetation is fully established.

4.3.10 Performance Confirmation

The CTW Demonstration Project achieved most of the performance objectives as established by the acceptance criteria from the demonstration plan. Six of the eight performance objectives were met during one year of operation (Table 4-2). The objectives for effluent toxicity and NPS removal were not assessed because higher than expected construction costs necessitated a reduction in project analytical costs. The permit for the outfall had changed from an individual to a multi-sector permit making the NPDES permit compliance performance objective inapplicable.

For the primary performance criteria of cost reduction, mission impacts, and land use, the wetland system achieved the performance criteria. The system is estimated to cost $3,000 to operate and maintain annually, which is only $500 more than expected. Even though the NPDES permit objective no longer applies, the wetland system achieved BOD_5 slug load reductions.

BOD_5 mass removal rates at greater than 220 kg/ha/d were higher than more than 97 percent of all of the annual average operational data values (N = 191) in the North American Treatment Wetland Database v. 2 [1]. The apparent wetland background or minimum

achievable BOD_5 concentration during a deicing event was relatively high at about 133 mg/L. This result was not entirely unexpected since Kadlec and Knight (1996)[13] estimate a background BOD_5 concentration of about 110 mg/L at an inlet BOD_5 concentration of about 2,000 mg/L. Lower outflow BOD_5 concentrations could likely be achieved with greater pretreatment (increased storage and reduced peak flow rate) before the CTW.

Peak concentration reductions were generally very high and were greater than 50 percent in 5 of the 10 individual events that were measured. BOD_5 mass removal efficiencies were much lower (-3 to 21 percent) due to very high incoming loads. It is likely that BOD_5 removal rates would have been higher in a fully matured and developed SSF CTW. The performance of this system can reasonably be expected to increase for the next several years and level out at a higher level than during this first year of operation. The wetland plant community should approach full coverage by the end of the 2003 growing season and performance during the upcoming winter of 2003–2004 will reflect the effect of that increased coverage.

The major limitation for this project was the site area constraint and lack of storage. The available area for the CTW was too small for the amount of flow and ADF application from the watershed. It is estimated that at least 2 to 2.5 acres of CTW would be required to fully treat the ADF entering the O/W separator.

5. Cost Assessment

The costs associated with discharging ADF wastes to a CTW versus a local POTW are presented in Tables 5-1 through 5-3. POTW discharge was selected for cost comparison since it is considered the ‘default’ treatment methodology for small to medium sized airports and military air facilities. These costs were evaluated for an average annual ADF usage of about 10,000 gallons. The life-cycle basis was a 20-year project life at a 6 percent discount rate. Actual usage in 2002-2003 during the CTW Demonstration Project was higher than average with over 50,000 gallons.

Annualized cost estimates were $26,940 (± $8,082) for the existing 0.6 acre CTW, $71,394 (± $21,418) for a full-scale CTW at this site (2 acres), and $105,182 (± $31,555) for transfer of the glycol-containing stormwater to a POTW for treatment and disposal. A full-scale CTW at this site, in comparison to a POTW, would result in an annual cost savings of approximately $33,788 (± $10,136).

Capital costs for the demonstration CTW and full-scale CTW have been estimated at $286,000 and $795,800, respectively. The most significant costs for both systems are equipment purchase and installation. The full-scale system has an added $70,000 cost for pretreatment and storage. Pretreatment already existed at Westover so there is no cost associated with pretreatment and storage for the demonstration wetland.

Assuming a facility has no existing treatment, the CTW technology is estimated to be about 32 percent less costly on an annual basis than the most likely alternative technology, which is discharge to the local POTW. Further, the treatment wetland would be much less costly compared to other available alternatives such as a fixed-film bioreactor. A bioreactor would have higher capital and operating costs.

Cost savings will be less if a facility has been discharging to the POTW and now chooses to install a full-scale CTW. This is because capital costs have already been expended for the POTW discharge and not for the CTW. The savings in annual costs with a CTW is $76,000 per year. The payback period for this scenario is 10.5 years.

Table 5-1. Costs Associated with the Collection, Storage and Controlled Release of ADF Stormwater to a POTW

Project Capital Cost	$315,000	Project Annual Costs	$79,700	Net Present Worth (20 yr)	$1,206,219	Annual Worth (20 yr)	$105,182
Direct Environmental Activity Process Costs			**$77,700**	**Indirect**			
Start-Up		**Operation & Maintenance**	**$77,700**	**Environmental**	**$2,000**	**Other Costs**	**$0**
Activity (capital cost)	**$315,000**	**Activity (annual cost)**	**$77,700**	**Activity (annual cost)**	**$2,000**	**Activity (annual cost)**	**$0**
Equipment purchase (1)	$225,000	Equipment labor (3)	$8,000	Compliance audits	$0	Process overhead	$0
Design	$30,000	labor to manage hazwaste	$0	Document maintenance	$0	Productivity/Cycle time	$0
Mobilization	$5,000	Utilities	$0	Environmental Mgt. Plans	$0	Worker injury/health costs	$0
Site preparation	$5,000	Treatment of by-products	$0	Reporting requirements	$0		
Permitting	$5,000	POTW disposal fees	$67,200	Analytical testing rqmts.	$2,000		
Installation	$30,000	Raw Materials	$0	Labor medical exam rqmts.	$0		
Construction Management	$ 10,000	Process chemicals/nutrients	$0	Waste transportation	$0		
Demobilization	$5,000	Consumables & supplies	$0	OSHA/EHS training	$0		
		Equipment maintenance	$2,500				
TOTAL	$315,000	TOTAL	$77,700	TOTAL	$2,000	TOTAL	$0

(1) 20,000 gal storage tank ($20,000), vacuum truck ($200,000), metering pump ($5,000)
(2) Discharge to POTW: ($0.80/lb BOD5)*(10000 gal ADF/yr)*(8.4 lb/gal) = $67,200/yr
(3) Assumes 2 operators for 40 hours per year at $100/hr
Net present and annual worth use a 6% interest factor or discount rate.

Table 5-2. Costs of Enhanced Biological Attenuation of ADF Runoff Using Constructed Wetlands (Demonstration)

Project Capital Cost	**$286,000**	**Project Annual Costs**	**$3,000**	**Net Present Worth (20yr)**	**$308,940**	**Annual Worth (20 yr life)**	**$26,940**
Direct Environmental Activity Process Costs				**Indirect**			
Start-Up	**$326,000**	**Operation & Maintenance**	**$6,900**	**Environmental**	**$2,000**	**Other Costs**	**$0**
Activity (capital cost)	**$286,000**	**Activity (annual cost)**	**$1,000**	**Activity (annual cost)**	**$2,000**	**Activity (annual cost)**	**$0**
Equipment purchase (1)	$116,000	Labor to operate equipment	$500	Compliance audits	$0	Process overhead	$0
Design	$44,000	labor to manage hazwaste	$0	Document maintenance	$0	Productivity/Cycle time	$0
Mobilization (2)	$27,000	Utilities	$900	Environmental Mgt. Plans	$0	Worker injury/health costs	$0
Site preparation	$10,000	Mgmt/Treatment of by-products	$0	Reporting requirements	$0		
Permitting	$5,000	Hazwaste disposal fees	$0	Analytical testing rqmts.	$2,000		
Installation	$50,000	Raw Materials	$0	Labor medical exam rqmts.	$0		
Construction Management	$29,000	Consumables/supplies/chemicals	$0	Waste transportation	$0		
Monitoring Equipment	$40,000	Monitoring Equipment	$5,000	OSHA/EHS training	$0		
Demobilization	$5,000	Equipment maintenance	$500				
		Operator training	$0				
TOTAL	$326,000	TOTAL	$6,900	TOTAL	$2,000	TOTAL	$0

Items in red are due to demonstration data collection requirements and would not be incurred in a real-world installation.
Net present and annual worth use a 6% interest factor or discount rate.
(1) Includes wetland media, liner, piping, and associated structures.
(2) Includes bid package, site visit, contractor selection, and equipment mobilization costs.

Table 5-3. Costs of Enhanced Biological Attenuation of ADF Runoff Using a Full Scale Constructed Wetland

Project Capital Cost	$795,800	Project Annual Costs	$4,000	Net Present Worth (20yr)	$818,740	Annual Worth (20 yr life)	$71,394
Direct Environmental Activity Process Costs				**Indirect Environmental**	**$2,000**	**Other Costs**	**$0**
Start-Up		**Operation & Maintenance**					
Activity (capital cost)	**$795,800**	**Activity (annual cost)**	**$2,000**	**Activity (annual cost)**	**$2,000**	**Activity (annual cost)**	**$0**
Equipment purchase (1)(2	$382,800	Labor to operate equipment	$1,000	Compliance audits	$0	Process overhead	$0
Pretreatment (3)	$70,000	Equipment maintenance	$1,000	OSHA/EHS training	$0	Worker injury/health costs	$0
Design	$50,000	labor to manage hazwaste	$0	Document maintenance	$0	Productivity/Cycle time	$0
Mobilization (4)	$30,000	Utilities	$0	Environmental Mgt. Plans	$0		
Site preparation (2)	$33,000	Mgmt/Treatment of by-products	$0	Reporting requirements	$0		
Permitting	$10,000	Hazwaste disposal fees	$0	Analytical testing rqmts.	$2,000		
Installation (2)	$165,000	Raw Materials	$0	Labor medical exam rqmts.	$0		
Construction Management	$50,000	Consumables/supplies/chemica	$0	Waste transportation	$0		
Demobilization	$5,000						
TOTAL	$795,800	TOTAL	$2,000	TOTAL	$2,000	TOTAL	$0

Net present and annual worth use a 6% interest factor or discount rate.
(1) Includes wetland media, liner, piping, and associated structures.
(2) Costs extrapolated from 0.6 acre system to 2 acre system (3.3 x higher)
(3) Estimate for appx. 70,000 gal pretreatment lagoon or oil/water separator.
(4) Includes bid package, site visit, contractor selection, and equipment mobilization costs.

6. Implementation Issues

6.1 Environmental Checklist

Each application of CTW technology will require different permitting requirements. Permitting varies by state and locality. Below are the two most significant permitting requirements that may have to be addressed.

- National Environmental Policy Act (NEPA) – a determination may be necessary to determine significant environmental impacts, if any
- Clean Water Act – through its National Pollution Discharge Elimination System (NPDES) an ADF CTW would be integrated into a stormwater management plan.

6.2 Other Regulatory Issues

Unless the facility uses over 100,000 gallons of ADF per year the CTW will be considered a best management practice (BMP) and become part of its base-wide stormwater pollution prevention plan. This plan is maintained and updated at the base. Future encounters with regulators are likely to occur during site inspections.

The information, lessons learned, and insight into the implementation process gained from this project can be used to determine if the CTW technology can be cost effectively applied to a particular installation. The technology should be considered a BMP. It should not be considered a treatment plant or treatment system since ADF runoff is associated with precipitation (stormwater) events and is not an industrial waste stream.

6.3 End-User Issues

The principal end-user concern for this technology is the possibility of increasing bird air strike hazard (BASH). The base commander was consulted several times before starting the project in order to get approval. The demonstration proved the concern to be unwarranted since a SSF CTW does not attract the birds of concern for BASH.

Other concerns for the end-user of a properly designed, fully functioning system should be minor. In the case of infrequent storm events during portions or the year in arid climates, a source of supply water may be necessary to insure plant health. An existing or new surface or groundwater supply could be used to keep the system from drying up.

There are currently no plans for implementation of this CTW technology at other Air Force or DOD installations. A thorough review of needs/opportunities should be conducted at all DOD installations that conduct aircraft deicing operations to determine if this technology can provide a feasible alternative to existing or planned control measures.

6.4 Cost Observations

The most significant costs for use of SSF CTWs for the treatment of ADFs are the capital costs. Of these costs, purchase and delivery of the bed media, bed liner, and excavation are the most significant. Besides the purchase and operation of the demonstration monitoring equipment, operation and maintenance costs for the system are low.

Site specific factors affect construction cost. At Westover ARB, additional costs for excavation were incurred because the system was built upon a slope. The slope required additional excavation to achieve the proper bed bottom level. Costs for the bed liner were significant. In the case of a SSF CTW built upon less permeable material (e.g. clay), the necessity for a liner could be avoided resulting in a cost savings.

Additional costs were incurred because of the procurement method used. A cost-plus type contract was used to acquire construction services. A firm-fixed price contract would have been more cost effective. The higher cost-plus contract costs are reflected in the design, mobilization and construction management costs in the Section 5 of this report.

6.5 Performance Observations

The constructed wetland system achieved most of the performance objectives as established by the acceptance criteria from the demonstration plan. Five of the six performance objectives were met during one year of operation. The objectives for effluent toxicity and NPS removal were not assessed because higher than expected construction costs necessitated a reduction in project analytical costs. The permit for the outfall had changed from an individual to a multi-sector permit making the NPDES permit compliance performance objective inapplicable.

For the primary performance criterion of cost reduction, mission impacts, and land use, the wetland system achieved the performance criterion. The system is estimated to cost $3,000 to operate and maintain annually, which is only $500 more than expected. Even though the NPDES permit objective no longer applies, the wetland system achieved BOD slug load reductions. Peak BOD concentration was reduced more than 80 percent in one deicing event. Flow-weighted mass reductions reached only 21 percent removal efficiency. Nevertheless Westover ARB plans to continue use and maintenance of the CTW because of the significant benefits documented by this demonstration project.

It is considered likely that the CTW system did not achieve a higher BOD mass removal because it was undersized for the actual ADF loads experienced during this performance period, there was insufficient pretreatment storage volume to reduce peak flow rates, and due to system immaturity. It is also considered possible that system performance suffered due to microbial toxicity from ADF additives because of the higher than normal ADF loading during this deicing season.

For these reasons it is recommended that additional funds be made available to continue monitoring of the CTW system during the next 3 to 5 years to develop a more complete picture of performance within the range of year-to-year climatic variations and due to system maturation.

6.6 Scale-Up

The most significant scale-up issue will be finding available land situated away from runways. A full-scale system at Westover would be 2.0 to 2.5 acres in size and would require a 70,000 gallon pretreatment lagoon or oil/water separator. Available land for full-scale implementations could be farther from deicing operations and require pumping and additional piping.

6.7 Other Significant Observations

In order to get a CTW system functional in its first deicing season, all construction contracts should be in-place by the previous fall (e.g. November). Construction should commence as early as possible during winter so planting can occur during the early part of the growing season (e.g. April).

Pretreatment and/or storage is necessary to reduce peak flows and loads. This 0.6-acre system relied upon a 35,000 gallon oil/water separator for pretreatment and had minimal flow equalization. Front end storage reduces peak flow and lessens the "shock" load of ADFs to the CTW.

Another observation was that there was microbial excessive growth and some clogging of the inlet pipe holes where nutrient rich water enters the CTW. This problem caused preferential flow at the ends of the inlet distribution pipe and probably reduced treatment efficiency. This problem was fixed after the demonstration period was over by enlarging the pipe orifices.

6.8 Lessons Learned

A larger SSF constructed treatment wetland would improve BOD mass load reduction efficiency. For better performance during peak or shock loading events, significant storage volume should be considered, using either a storage tank or pond. Influent pipe clogging resulted because of insufficient hole sizes in the pipe. These holes should be 1 to 1.5 inches in diameter for both the influent distribution and effluent collection pipes.

7. References

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7. Points of Contact

Point of Contact	Organization	Phone/Fax/email	Role in Project
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Barbara Sugiyama	Naval Facilities Engineering Service Center 1100 23rd Avenue Port Hueneme, CA 93043-4370	ph: 805.982.1668 fax: 805.982.4304 nelsonbm@nfesc.navy.mil	Co-Principle Investigator
Robert L. Knight, PhD	Wetland Solutions, Inc. 2809 NW 161 Court Gainesville, FL 32609	ph: 386.462.1003 fax: 386.462.3196 bknight@wetlandsolutionsinc.com	Consulting Wetland Scientist
Jack Moriarty	West Over Air Reserve Base	ph: 413.557.2434	Host Activity Representative
Maj. Jeff Cornell, PhD	U.S. Air Force Institute of Technology	ph: 210.536.4331	Air Force Partner
Mark Hernandez, PhD	University of Colorado	ph: 303.492.5991	
Devon Cancilla, PhD	Western Wash. Univ.	ph: 360.650.7785	

Appendix A

SAMPLING AND ANALYSIS PLAN

This sampling and analysis plan (SAP) was created using the U.S. EPA's Data Quality Objective (DQO) process as shown in EPA QA/G-4, Guidance for the Data Quality Objective Process (U.S. EPA, 1994). In addition, this SAP conforms to our Quality Assurance Project Plan (QAPP) as contained in Appendix C of this document.

Data collection requirements for this project call for a significant number of samples and analyses for a large set of contaminants and water quality parameters. A small portion of this analytical data requirement will be in a matrix other than surface water, namely wetland vegetation and bed media. The vast majority of this demonstration's sampling and analysis will be directed towards surface water sampling efforts including:

- grab sampling of surface waters for routine sampling,
- flow-weighted sampling of surface waters during deicing and precipitation events,
- routine and selected water sample collection from piezometers,
- field measurement of general water chemistry, and
- semi-continuous measurement of water quality parameters.

A.1 SAMPLING SCHEDULE

Tables A-1 through A-4 include the planned **minimum** sampling and analysis schedule for this project. Tables A-1 and A-2 indicate sampling frequencies during the baseline monitoring period, which is from October 1, 2000 through September 30, 2001. Tables A-3 and A-4 address the sampling schedule for the experimental or portion of this demonstration. The experimental timeframe is October 1, 2001 through March 1, 2003. Tables A-1 and A-3 address sampling during deicing events and Tables B-2 and B-4 indicate sampling requirements throughout the year.

Table A-1: Baseline - Event Monitoring

Parameter	# Stations	Events/Yr	Samples/Event	Total Samples	Lab
BOD5	1	4	4	16	Contract
COD	1	4	4	16	U. Col
Propylene glycol	1	4	4	16	U. Col

Table A-2: Baseline - Routine Monitoring

Parameter	# Stations	Events/Yr	Total Samples	Lab
BOD5	2	16	32	Contract
COD	2	16	32	U. Col
Propylene glycol	2	16	32	U. Col

Table A-3: Demonstration - Event Monitoring

Parameter	# Stations	Events/Yr	Total Samples	Lab
BOD5	2	12	24	Contract
COD	2	12	24	U. Col
Propylene glycol	2	12	24	U. Col

Table A-4: Demonstration - Routine Monitoring

Parameter	# Stations	Events/Yr	Samples/Event	Total Samples	Lab
BOD5	2	4	2	8	Contract
COD	2	4	2	8	U. Col
Propylene glycol	2	4	2	8	U. Col

These tables represent only minimum frequencies, number of stations, total samples, and analytes. Additional surface water parameters will be analyzed, but only the three analytes shown in these tables are required for each sampling event. Also, bed media and vegetation will be collected and analyzed to verify that recalcitrant compounds do not accumulate or translocate to dangerous levels.

Table A-5 summarizes the proposed sampling activities at these stations and their required sampling frequency. Water sample collection will be both manual and automated. Manual sample collection will be necessary at some stations and times. The O/W separator inlet, separator outlet/wetland inlet, and wetland outlet will be sampled with a stormwater autosampler and monitored semi-continuously (e.g. once per hour) using water quality multiprobe.

Table A-5 Monitoring stations and sampling frequency.

Station Code	Station Description	Flow	Field Parameters[1]	Analyical Parameters[1,2]	Project Stage
1	Oil/water separator inlet	C	O	O	B and D
2	Oil/water separator outlet	C	O, Event, M	O, Event	B and D
3	Combined wetland outlet	C	O, Event, M	O, Event	D only
4	Outfall 001	C	O	O	B and D
A1	1st Piezometer		O	O	D only
A2	2nd Piezometer		O, M, Event	O, Event	D only
A3	3rd Piezometer		O	O	D only

C = continuous measurement using stage vs. discharge relations
M = multiprobes (semi-continuous)
O = monthly or other frequency for grab samples
Event = event sampling

B = Baseline
D = Demonstration

Notes: [1]field parameters include temperature, pH, Eh,DO, turbidity, and conductivity
[2]surface water parameters include those listed in Table B.6

Flow will be estimated using water levels, weir equations, and calibrated discharge coefficients in order to develop stage discharge relationships. Thus, only gauge pressure at the flow stations will be required to estimate flow during the project. Flow measurement will allow calculation of pollutant mass loadings entering and exiting the O/W separator and the constructed wetland and are essential for estimating treatment performance for the system.

Precipitation will be measured onsite with a tipping bucket and checked against Westover's weather station precipitation records. Evapotranspiration will be estimated as a factor (0.78) of local pan evaporation as reported by the closest official weather station.

A.2 ANALYTICAL LABORATORY SELECTION

Two types of analytical laboratories are necessary for this demonstration. We will use the laboratory at University of Colorado, Boulder for the analysis of the ADAF additive components (e.g. 4-MeBT), and propylene glycol analysis. Analysis for this and other ADAF additive compounds is an expertise that can only be performed at select laboratories properly setup to do so. For analysis of more routine analytes, such as for BOD_5, samples will be sent to a locally EPA certified lab or to an NFESC contract lab. Western Washington University (WWU) is also an integral component of the project's analytical laboratory program. WWU will act as an independent, third party and perform QA/QC functions (e.g. lab auditing) and will develop the projects quality assurance project plan (QAPP).

A.3 ANALYTICAL METHODS

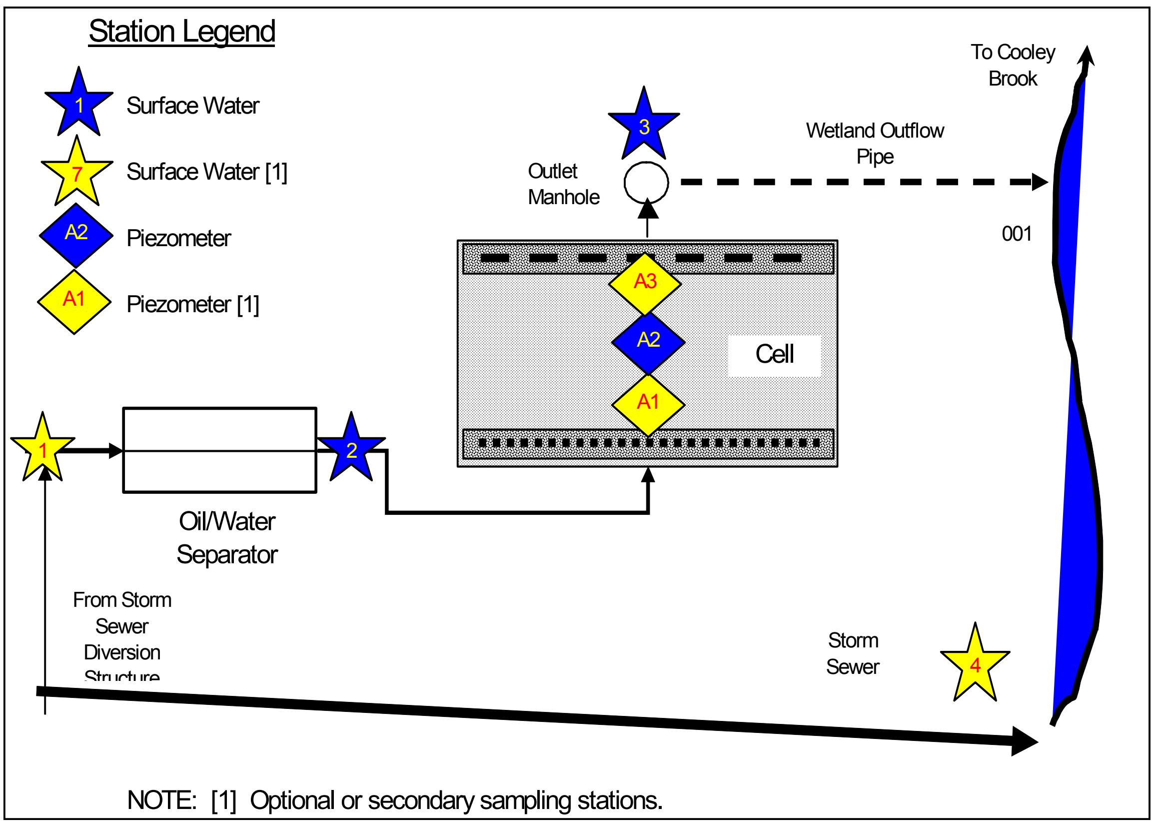
The analytical methods used will be standard EPA Methods (or equivalent) for all but the ADAF additives. As previously mentioned, the University of Colorado, Boulder will be performing analytical procedures for the additives of concern. Since no standard method exists for many of the additives, Boulder will be using a gas chromatograph technique developed at the university. The analytical laboratory at WWU is also capable of accurate analysis of ADAF additives. Together and separately, the two universities will develop a protocol/method for analyzing select ADAF components (i.e. 5-MeBT). Additional information on the analytical methods is found in the QAPP (Appendix B).

A.4 SAMPLE COLLECTION

Figure A-1 illustrates the proposed sampling stations for this SSF CTW Demonstration project. Overall, there are 4 proposed surface water stations and 3 shallow piezometers located in the one wetland cells. Surface water samples will be collected by hand for routine sampling and by autosampler for deicing events.

The piezometers will be located at the ¼, ½, and ¾ end points of each SSF wetland cell. These stations will allow documentation of water levels through the cells and estimation of internal depuration of glycol and contaminants within the gravel beds. Only one piezometer from each cell will be sampled during the experiment on the routine schedule. It is possible these internal wetland sampling stations will be of use for additional research work and perhaps troubleshooting poor performance, if needed.

Figure A-1 Proposed sampling stations for the treatment wetland system.



A.5 PARAMETERS FOR ANALYSIS

While only selected parameters will be used for the majority of data collection associated with this project, sampling for other parameters will occur. Table A-6 lists all parameters and associated standard methods that could be analyzed for during selected sampling events.

Some stations will be used for continuous water quality monitoring of pH, Eh, dissolved oxygen, temperature, conductivity, and turbidity. Additionally, research funding

and opportunities may arise that will allow the additional data collection for an enhanced analytical data set.

Table A-6: Surface Water Sampling and Analysis Parameters and Methods

Parameter	Analytical Method	Analytical Lab
BOD_5	405.1 [1], 5210B [2]	Contract
COD	410.1 et al. [1], 5220B+C or D [2]	Cont. & Ucol.
Color	110.2 [1], 2120 B [2]	Contract
Propylene Glycol	8015M [6]	U. Colorado
ADAF additives	[3]	U. Colorado
TOC	415.1/415.2 [1], 5310B [2]	Contract
TSS	160.2 [1], 2540C [2]	Contract
Nitrate/Nitrite	353 Series [1], 4500 Series [2]	Contract
Kjeldahl Nitrogen	351 Series [1], 4500 Series [2]	Contract
Total Phosphorus	365 Series [1], 4500 Series [2]	Contract
Oil & Grease	413 Series [1], 5520 Series [2]	Contract
WET – algae	EPA Acute Whole Effluent Toxicity Tests [4]	U. Colorado
WET- bacterium	EPA Acute Whole Effluent Toxicity Tests [4]	U. Colorado
WET – water flea	EPA Acute Whole Effluent Toxicity Tests [4]	U. Colorado
WET – minnow	EPA Acute Whole Effluent Toxicity Tests [4]	U. Colorado
VOCs	624 [5], 6210 [2]	Contract
SVOCs (PAHs)	625 [5], 6410 [2]	Contract
Metals (15)	200.7 [1]	Contract

[1] Method reference from "Methods for Chemical Analysis of Water and Wastes", USEPA, EPA 600/4-79-020, Revised March 1983.
[2] Method reference from "Standard Methods for the Examination of Water and Wastewater", AWWA-WPCF-APHA, 17th Edition, 1989.
[3] Method does not exist. WWU and U. Colorado protocols to be used.
[4] WET methodology as contained in "Methods for Measuring the Acute Toxicity of Effluents to Aquatic Organisms." EPA-600/4-90-027.
[5] Method reference from "Test Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater," EPA 600/4-82-057.
[6] Method from "Test Methods for Evaluating Soled Waste, Physical/Chemical Methods", USEPA , SW-846.

The final monitoring component is for wetland health. Toward this end, periodic sampling of wetland vegetation and bed media will be collected. Wetland vegetation will be sampled for both above-ground and below-ground biomass. While not determined at this time, vegetation sample analyses are expected to track chemicals of concern within the

treatment system. Vegetation cover density will also be tracked during the experiment. The goal is to ascertain that the wetland system is in good health and functioning properly.

Appendix B
Quality Assurance Project Plan (QAPP)

B.1 PROJECT MANAGEMENT

B.1.1 Project Organization

Jeff Marqusee, Environmental Security Technology Certification Program, Sponsor

Jeff Karrh, Naval Facilities Engineering Service Center, Overall Project Management

Devon Cancilla, Ph.D., Western Washington University, Quality Assurance Officer

Robert L. Knight, Ph.D., Implementation and Oversight

Mark Hernandez, Ph.D., Univ. Colorado Boulder, Analytical Services Coordinator

Jack Moriarty, Westover Air Reserve Base, Field Quality Assurance Officer

B.1.2 Purpose

The purpose of this project is to demonstrate the ability of horizontal, subsurface flow treatment wetlands to mitigate the adverse environmental and mission impacts associated with aircraft deicing waste streams in a cost-effective manner. This QAPP will aid in the collection of quantitative, analytical data of known and necessary quality to support the evaluation of this demonstration. The primary **quantitative** performance objectives and their corresponding performance metrics are given in Table B-1. These objectives are for (a) cost-effectiveness, and (b) treatment performance. A discussion of all performance objectives (quantitative, qualitative, primary, and secondary) can be found in section 5.1 of the demonstration plan.

Table B-1: Primary Project Performance Objectives and Performance Criteria.

Performance Objective	Type	Expected Performance and Metrics
Reduced Cost	Quantitative	Annualized cost < $ per lb BOD5 removed per year ($/lb/yr) or annual cost < $2500
Slug Load Treatment	Quantitative	
NPDES Permit Compliance	Quantitative	[BOD5] < 30 mg/L monthly mean

B.1.3 Project/Task Description and Schedule

The project will be broken into four parts: baseline monitoring, construction, establishment, and experiment. The schedule for each part appears in Table B-2.

Table B-2. Project Schedule.

Item	Start Date	End Date	Duration (Days)
Baseline Monitoring	01OCT00	30SEP01	365
Construction	01APR01	15JUN01	76
Establishment	15JUN01	30SEP01	76
Experiment	01OCT01	28FEB03	516

B.1.4 Quality Objectives and Criteria for Measurement Data

Table B-3 lists the analytical methods to be used during this project for measuring performance of the treatment wetland system. Specifically, these methods will be used to measure contaminant levels associated with the primary project objectives: BOD_5, COD, and PG.

Table B-3: Parameter and Method for Evaluating Primary Quantitative Objectives

Parameter	Analytical Method
BOD5	405.1 [1], 5210B [2]
COD	410.1 et al. [1], 5220B+C or D [2]
Propylene Glycol	8015M [3]

[1] Method reference from "Methods for Chemical Analysis of Water and Wastes", USEPA, EPA 600/4-79-020, Revised March 1983.
[2] Method reference from "Standard Methods for the Examination of Water and Wastewater", AWWA-WPCF-APHA, 17th Edition, 1989.
[3] Method from "Test Methods for Evaluating Soled Waste, Physical/Chemical Methods", USEPA , SW-846.

The Table B-3 contaminants do not represent the entirety of this project's analytical requirements. Table B-4 contains all of the analytical parameters and methods that are expected to be used on this project. However, these additional parameters are not part of the measurement criteria used for evaluating this project's success or failure to meet the primary objectives. Rather, they will be used as indicators for evaluating the secondary objectives. Because of a limitation in budgeted analytical costs, sampling and analysis for parameters not listed in Table B-3 will not undergo the same level of quality assurance as specified in Table B-6 of this QAPP.

This project requires the use of both standard analytical methods and "non-standard" methods or methods under development. Standard analytical methods are those developed by a responsible agency and freely published for use by analytical laboratories. Methods published by the USEPA or American Water Works Association (Standard Methods for the Examination of Water and Wastewater) are examples of standard analytical methods. Parameters such as chemical oxygen demand, biological oxygen demand or turbidity can all be analyzed using standard methods. These methods have well defined method performance characteristics and have undergone multiple laboratory validation. Method performance characteristics include statements of method precision, accuracy, recovery, contamination and sensitivity (PARCS). These methods include established and detailed data acceptance/rejection criteria.

The second type of analytical methods necessary for the project are non-routine in nature and classified as methods under development. These developmental methods are necessary for parameters such as the tolyltriazoles. These methods have not undergone multiple laboratory validation and therefore do not have well defined method performance characteristics. It is proposed that the Association of Official Analytical Chemists (AOAC) International Peer-Verified Methods Program guidelines be followed to assess and document these analytical methods for use in the project. During the method development stage, the appropriate quality control/quality assurance steps will be established for the specific method.

Definition of the method's performance characteristics include statements of accuracy, recovery, calibration, linearity, limit of detection, limit of quantification, precision, sensitivity, and specificity. Once the performance characteristics have been defined, the method is documented in such a manner that another independent laboratory could obtain similar analytical results when following the documented method.

Table B-4 Surface Water Sampling and Analysis Parameters and Methods

Parameter	Analytical Method	Analytical Lab
BOD5	405.1 [1], 5210B [2]	Contract
COD	410.1 et al. [1], 5220B+C or D [2]	Cont. & Ucol.
Color	110.2 [1], 2120 B [2]	Contract
Propylene Glycol	8015M [6]	U. Colorado
ADAF additives	[3]	U. Colorado
TOC	415.1/415.2 [1], 5310B [2]	Contract
TSS	160.2 [1], 2540C [2]	Contract
Nitrate/Nitrite	353 Series [1], 4500 Series [2]	Contract
Kjeldahl Nitrogen	351 Series [1], 4500 Series [2]	Contract
Total Phosphorus	365 Series [1], 4500 Series [2]	Contract
Oil & Grease	413 Series [1], 5520 Series [2]	Contract
WET – algae	EPA Acute Whole Effluent Toxicity Tests [4]	Contract
WET- bacterium	EPA Acute Whole Effluent Toxicity Tests [4]	Contract
WET – water flea	EPA Acute Whole Effluent Toxicity Tests [4]	Contract
WET – minnow	EPA Acute Whole Effluent Toxicity Tests [4]	Contract
VOCs	624 [5], 6210 [2]	Contract
SVOCs (PAHs)	625 [5], 6410 [2]	Contract
Metals (15)	200.7 [1]	Contract

[1] Method from "Methods for Chemical Analysis of Water and Wastes", USEPA, EPA 600/4-79-020, Revised 3/83.

[2] Method from "Standard Methods for the Examination of Water and Wastewater", AWWA-WPCF-APHA, 17th Edition, 1989.

[3] Method does not exist. WWU and U. Colorado protocols to be used.

[4] WET methodology as contained in "Methods for Measuring the Acute Toxicity of Effluents to Aquatic Organisms." EPA-600/4-90-027.

[5] Method from "Test Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater," EPA 600/4-82-057.

[6] Method from "Test Methods for Evaluating Soled Waste, Physical/Chemical Methods", USEPA , SW-846.

B.1.5 Special Training Requirements/Certification

Each technician performing the analyses at the contract laboratories will need to demonstrate proficiency with the analytical methods before the analysis of real samples begins. This should be done according to established protocols that are in place at each laboratory.

B.1.6 Documentation and Records

All analytical and toxicological samples require unique sample identification numbers/codes, such that each sample can be traced from the time it is collected. Specifically, records must:

Field records - Each sample collected in the field will be labeled with the sample identification code. Chain-of-Custody forms will be used to record the sample identification code, sample location, date and time collected, sample matrix, and technician name. A note of the sampling event will be entered into a field notebook (located onsite), along with general observations/notes (e.g. weather), and notes of potentially useful information. Table B-3 presents the information expected from various site-related activities.

Laboratory records – Lab records should include documentation of sample labeling, including date received, matrix, and sample identification code at a minimum. The analytical reports generated by the laboratory should include QA/QC data, which is outlined in section 2.5 of this document.

For all data both a hard copy and an electronic copy will be generated. Each copy should include QA/QC data. The default format for the electronic copy will be in a format that can be read by Microsoft Excel 97, with the possibility of agreeing on an alternate software platform in the future.

B.2. MEASUREMENT/DATA ACQUISITION

B.2.1 Sampling Process Design (Experimental Design)

This section highlights the sampling and analysis to be performed for the aircraft deicing SSF CTW demonstration. Data collection requirements for this project entail a significant number of sampling and analyses for a large set of contaminants and water quality

parameters. Consequently, analytical costs can easily exceed the project budget for data. Therefore, the number of samples, sampling frequency, and sampling stations have been "optimized" to provide the project data requirements with minimum analytical costs. A small portion of this analytical data requirement will be in a matrix other than surface water, namely wetland vegetation and bed media. The vast majority of this demonstration's sampling and analysis will be directed towards surface water sampling efforts including:

- biweekly discrete or grab sampling of surface waters (routine sampling),
- flow-weighted sampling of surface waters during precipitation and deicing events,
- water sample collection from piezometers (routine),
- biweekly field measurement of general water chemistry (i.e. BOD), and
- continuously measured water quality parameters.

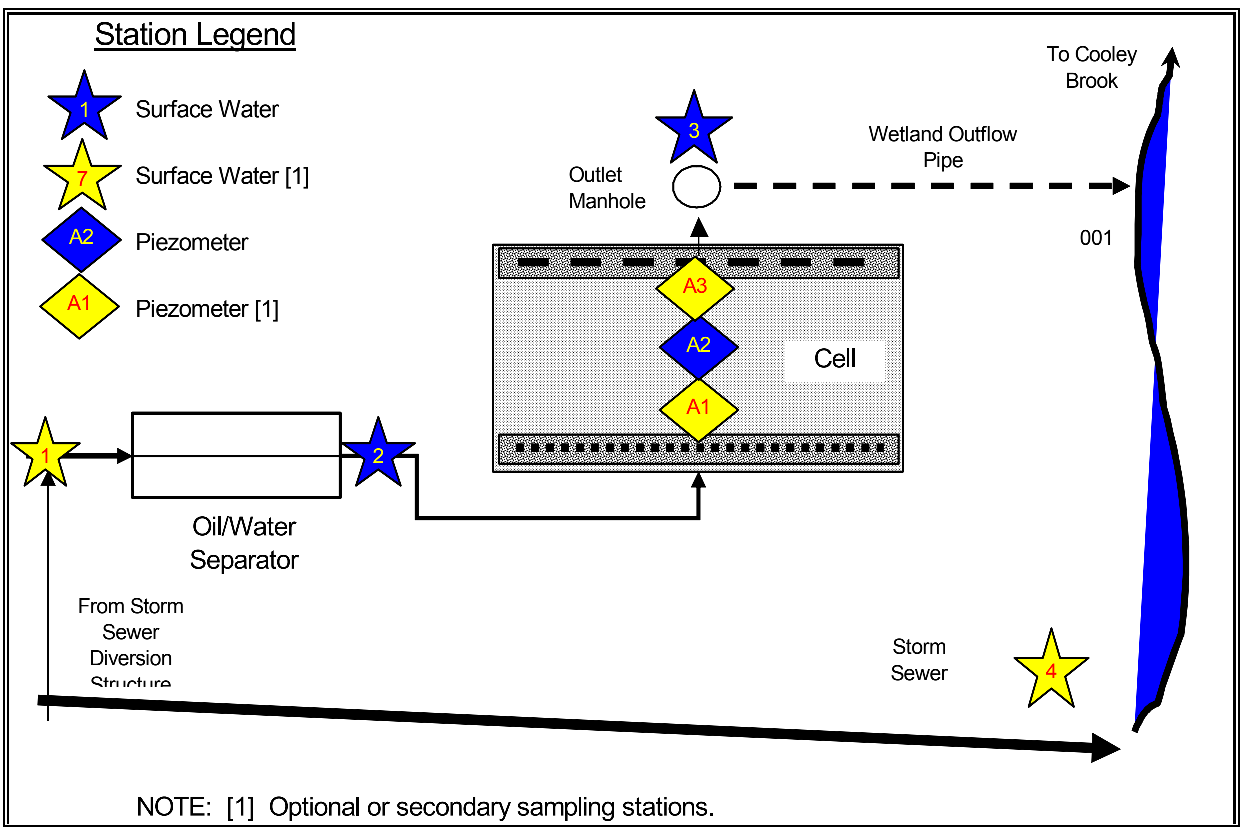


Figure B-1 The proposed sampling stations for the SSF CTW Demonstration project.

Sampling for this project is broken into 2 time periods, baseline monitoring and experiment monitoring. That is, pre- and post-wetland measurements will be collected. Both event and routine sampling will take place during each time period. A precipitation event will be defined as a precipitation event in which more than 0.10 inch of water (or an equivalent amount of snow) falls in a one half-hour period. A deicing event is the arrival of propylene glycol to the treatment system. We expect to sample four "events" per year.

As shown in Figure B-1 above, there are 4 proposed surface water stations and 3 piezometers located in the two wetland cells. Also, 20% of the analytical budget has been allocated towards QA/QC samples. The specific QA/QC procedures will be added to this plan after discussions with the contract laboratories, as contract labs often have established QA/QC procedures.

B.2.2 Sample Collection Requirements

The sample collection requirements will be solidified when the contract laboratory is chosen and the specific sampling methods are decided upon. At a minimum, the sample collection requirements of each analytical method will be followed. For example, the BOD_5 method outlined in method 5210 (see table below) requires that samples be kept in cold storage at or below $4^{O}C$ if not analyzed within 2 hours of collection, and that the sample must be analyzed within 24 hours of collection. Also, chilled samples should be warmed to $20 \pm 3^{O}C$. The specific methods should be standard methods, which are no less rigorous than those set forth in Table B.4.

B.2.3 Sample Handling and Custody Requirements

A Chain of Custody will accompany each sample group or batch submitted to the contract laboratories, and will include the parameter to be measured, sample matrix, amount of sample submitted, storage condition at submission, storage condition requirements, pretreatment requests, analysis turnaround time, and priority of analysis.

B.2.4 Quality Control Requirements

The minimum quality control requirements for all laboratory analyses appear in Table B-6 below. The overall goal of the Quality Control program will be to provide supporting PARCS (precision, accuracy, recovery, contamination, and sensitivity) data with each analytical measurement to help ensure that the data are valid. QA/QC procedures will be defined for both field collection of samples and laboratory analysis of samples. Each field sampling event will contain travel blanks, and travel spikes (where applicable), totaling no less than 5% of the total sample number. Also, field duplicates will be taken in an effort to ensure precision. Field duplicates should account for no less than 5% of the total sample load.

Table B-6 Minimum recommended quality control levels[1]

QC ELEMENT	RECOMMENDATION:MINIMUM LEVEL OF ANALYSIS
Analyst Team Proficiency	Four control sample analyses showing acceptable precision and accuracy Concentration levels ranging between 5 and 50 times method detection limit
Known Additions	Known additions should make up 10% of sample run (if duplicates are not run). Known additions plus duplicates should make up 10% of the sample run
CRMs/RMs Control Samples	One sample run each day or when know additions do not result in acceptable results
Reagent Blanks	Minimum 5% of the sample load or as required
Calibration	Minimum of 3 concentration levels (first degree curve). Minimum of 4 concentration levels (second degree curve). Curve is verified daily by analyzing one or more standards in the linear range
Duplicates	Minimum of 5% of the sample load

1. Standard methods, 18th Edition, APHA, AQQA, WEF.

Laboratory sample analysis should include method blanks (also called reagent blanks) and method spikes (where applicable), which should total no less than 5% of the total sample number. Known additions or Certified Reference Materials should be used to ensure accuracy, and should make up no less than 5% of the total sample number. All calibration curves should be verified daily. In absence of more strict criteria, the 20% rule should be applied. That is, all measured values should be within 20% of their accepted values. If these criteria are not met, the measurements should be repeated and /or appropriate corrective action taken.

The level of precision expected for low-level duplicates is method-specific, and this information appears in Table B-5. The QA/QC procedures set forth in this section are the bare minimum necessary. All QA/QC data will be reported with data generated for each batch of samples and it will be reviewed quarterly by the personnel at WWU following criteria outlined in the USEPA's Guidance for Data Quality Assessment and as well as Guidelines for both Organic and Inorganic Data Review.

Table B-5 Precision Specifications for BOD_5, COD, and Propylene Glycol.

Parameter	Analytical Method	Precision of Low-Level Duplicates
BOD5	405.1 [1], 5210B [2]	+/- 25%
COD	410.1 et al. [1], 5220B+C or D [2]	+/- 25%
Propylene Glycol	8015M [3]	+/- 40%

[1] Method reference from "Methods for Chemical Analysis of Water and Wastes", USEPA, EPA 600/4-79-020, Revised March 1983.
[2] Method reference from "Standard Methods for the Examination of Water and Wastewater", AWWA-WPCF-APHA, 17th Edition, 1989.
[3] Method from "Test Methods for Evaluating Soled Waste, Physical/Chemical Methods", USEPA , SW-846.

B.2.5 Instrument/Equipment Testing, Inspection, and Maintenance Requirements

Each instrument used in this study will be tested during a readiness-to-perform period. Instruments will be tested and inspected regularly according to the manufacturer's specifications and the individual laboratory's procedures. Control charts demonstrating adequate method precision, accuracy, recovery and contamination will be maintained where appropriate. Continuing calibration verification (CCV) will conducted for specific instruments where appropriate.

B.2.6 Instrument Calibration and Frequency

The USEPA's Contract Laboratory Program National Functional Guidelines for Organic (or Inorganic) Data Review will be used as a framework to establish calibration procedures, quality control checks and corrective actions. In the case of routine methods, control charts will be used to ensure method performance in support of the PARCS statements. In the case of non-routine methods, a 20% rule will be established until sufficient data is collected to statistically define control limits. For example, values to determine method accuracy must not be greater than 20% of the target value. Corrective actions will be taken as dictated by the quality control elements used to evaluate the PARCS

and other method performance criteria and will be appropriate to meet initial operating conditions of the analytical method.

B.2.7 Data Management

Data generated from this effort will occur in the field, in the laboratory, or remotely from a data acquisition system (DAS). Field data will be collected in a dedicated field notebook or on standard forms (i.e. sample chain-of-custody forms). Laboratory data will be collected in dedicated lab notebooks or forms. Field or lab photographs will be documented in the appropriate notebook. Data generated from the DAS will follow the manufactures electronic format. Data acquisition from the DAS will occur at frequencies necessary and sufficient for retrieval from data logger's extended memory.

All data will have specific storage and archiving procedures. Field and lab data collected in notebooks will periodically photocopied and sent to NFESC. NFESC will convert all hard copy field and lab data into electronic format. All electronic data will be sent to or collected by NFESC as generated.

Converted field/lab data and electronic data sets will be archived quarterly. For the field and lab data, this means archiving hard photocopies in the project file and storing electronic data on multiple computer systems and a removable mass media storage device. Electronic data from the DAS will be appended to subsequent quarterly archives so only one master archive file exists. Archived data will be stored on at least two computers and on a removable mass media storage device. All raw data, documentation, records, protocols, reports, correspondence, and other pertinent information will be archived and retained.

B.3. DATA VALIDATION AND USABILITY

B.3.1 Data Review, Validation, and Verification Requirements

All the data generated in this project will be reviewed and verified. The QA/QC data will be scrutinized to insure that the data are credible.

B.3.2 Validation and Verification Methods

The pathway by which field and laboratory data will be validated and verified is depicted in Figure B-2. All non-analytical data, including laboratory notebooks, photographs, notes, etc. will be sent directly from the field to the project manager for verification. Analytical data will be reviewed on several levels before it is accepted. First, the field technician will be responsible for adequate sampling and labeling. The analytical laboratory will be responsible for internal quality assurance/quality control verification. The quality assurance officer (WWU) will review all data submitted by the analytical laboratories to ensure adequate QA/QC throughout the entire project. Final review for both the laboratory and the field data will rest with the project manager.

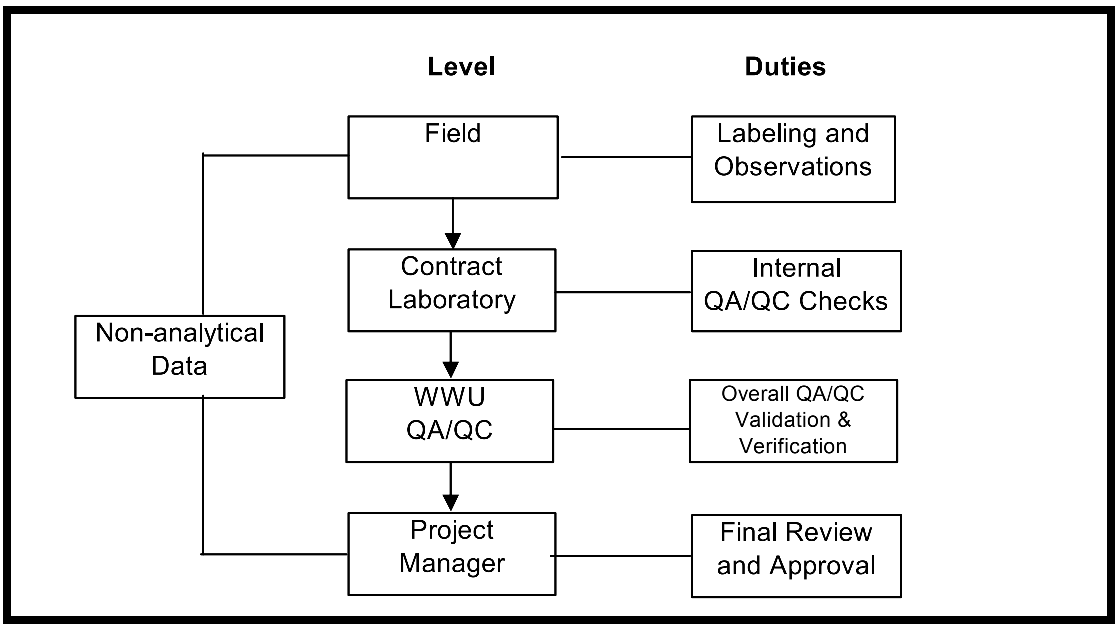
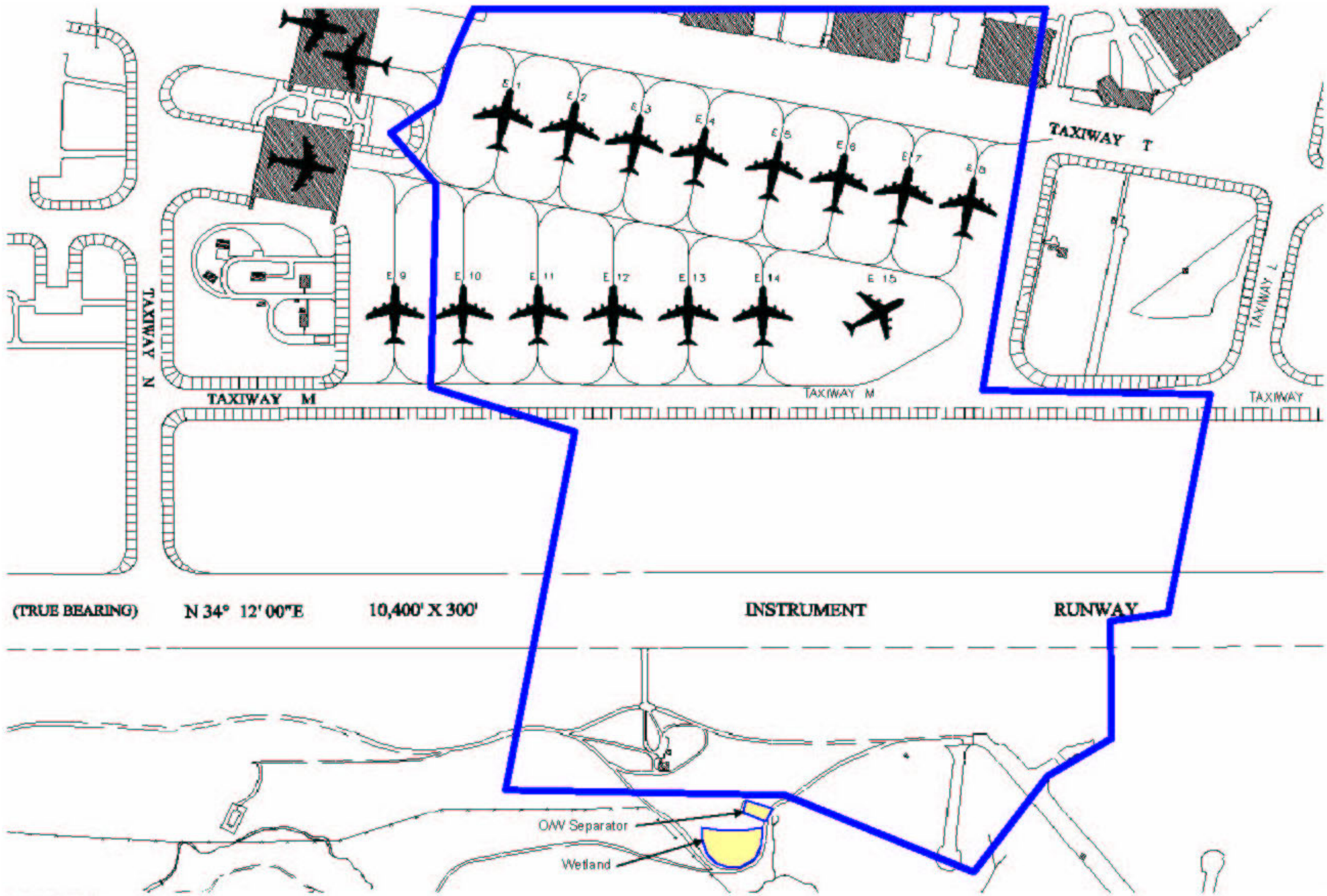


Figure B-2 Organization data review, validation, and verification responsibilities.

This Quality Assurance Project Plan (QAPP) is based on *EPA Guidance for Quality Assurance Project Plans, EPA WA/G5, EPA/600/R-98/018.*

Appendix C
Westover ARB Deicing Logs 1997 – 2003



APPENDIX C-1

Project Watershed Identifying De-icing Locaitons at the Westover Air Force Reserve Base, Chicopee, MA

APPENDIX C

WESTOVER AIR RESERVE BASE DEICING LOGS 1997 - 2003

FY_Year	Date	Aircraft Type	Aircraft Tail #	Location Deiced	Deicing Fluid Used (Gallons) Facility	To Outfall 001	Remarks
FY1998	11/21/97	C-21 A	84-0078	PAD 23	5		Transient
FY1998	12/10/97	MC-130E	64-0565	PAD 19	290		Transient
FY1998	12/11/97	AC-130 U	90-0163	PAD 19	70		Transient
FY1998	12/11/97	HC-130 P	65-0991	PAD 19	70		Transient
FY1998	12/11/97	AC-130 H	69-6575	PAD 19	60		Transient
FY1998	12/12/97	MC-130 H	90-0162	PAD 23	200		Transient
FY1998	12/12/97	MC-130 H	90-0161	PAD 23	200		Transient
FY1998	12/12/97	MC-130 E	64-0565	PAD 19	150		Transient
FY1998	12/12/97	AC-130 U	90-0163	PAD 19	150		Transient
FY1998	12/13/97	C-5 B	87-0043	PAD 23	250		Transient
FY1998	12/13/97	C-130 H	92-3283	PAD 23	100		Transient
FY1998	12/13/97	C-141 B	66-0155	PAD 23	175		Transient
FY1998	12/13/97	C-141 B	66-0131	PAD 23	175		Transient
FY1998	12/13/97	C-130 H	92-3281	PAD 23	100		Transient
FY1998	12/13/97	MC-130 H	83-1212	PAD 23	100		Transient
FY1998	12/13/97	MC-130 H	89-0280	PAD 23	100		Transient
FY1998	12/13/97	C-141 B	66-0192	PAD 23	200		Transient
FY1998	1/17/98	C-130 H	87-9281	PAD 05	40		Transient
FY1998	1/17/98	C-130 H	89-9104	PAD 05	40		Transient
FY1998	1/25/98	C-141 B	66-0130	PAD 05	50		Transient
FY1998	5/2/98			PULL-THRU HGR B-7040	80		Ags
FY1998	5/2/98			PULL-THRU HGR B-7040	50		Ags
FY1999	11/24/98	E-3B	77-0355	PAD 23	75		Transient
FY1999	11/24/98	E-3B	77-0355	PAD 23	75		Ags
FY1999	1/8/99	C-2 A	16-2160	PAD 23	50		Transient
FY1999	1/8/99	C-2 A	16-2160	PAD 23	450		Ags
FY1999	1/8/99	C-2 A	16-2160	PAD 23	500		Ags
FY1999	1/8/99	C-2 A	16-2160	PAD 23	200		Ags
FY1999	1/8/99	C-2 A	16-2160	PAD 23	500		Ags
FY1999	1/8/99	C-2 A	16-2160	PAD 23	500		Ags
FY1999	1/12/99	C-130 E	64-0498	PAD 23	100		Transient
FY1999	1/12/99	C-130 E	64-0498	PAD 23	100		Ags
FY1999	1/12/99			ECHO-14	50		Ags
FY1999	1/12/99			ECHO-14	180		Ags
FY1999	1/28/99	C-26 B	91-0513	PAD 05	20		Transient
FY1999	1/28/99	C-26 B	91-0513	PAD 05	300		Ags
FY1999	1/28/99	C-26 B	91-0513	PAD 05	300		Ags
FY1999	1/28/99	C-26 B	91-0513	PAD 05	250		Ags
FY1999	1/28/99	C-26 B	91-0513	PAD 05	250		Ags
FY1999	1/28/99	C-26 B	91-0513	PAD 05	350		Ags
FY1999	1/29/99			ECHO-5	350	350	Ags
FY1999	1/29/99			ECHO 5 & 9	175	175	Ags
FY1999	1/29/99			ECHO-5	200	200	Ags
FY1999	1/29/99			ECHO-5	650	650	Ags
FY1999	2/25/99	F-18 A		PAD 05	30		Ags
FY1999	2/25/99	F-18 A		PAD 05	200		Ags
FY1999	2/25/99	F-18 A		PAD 05	240		Ags
FY1999	2/25/99	F-18 A		PAD 05	150		Ags
FY1999	2/25/99	F-18 A		PAD 05	250		Ags
FY1999	2/26/99	C-5 A	8 215	ECHO-1	335	335	Ags
FY1999	2/26/99	C-5 A	8 215	ECHO-1	500	500	Ags
FY1999	3/6/99	UC-35	97-0103	PAD 05	50		Transient
FY1999	3/7/99	C-130 E	63-7823	PAD 05	755		Transient
FY1999	3/12/99	C-130 E	63-7868	PAD 05	40		Transient
FY2000	1/14/00	KC-135 E	57-1443	PAD 05	50		Transient
FY2000	1/14/00	C-141 B	66-7952	PAD 05	300		Transient
FY2000	1/14/00	KC-135 E	57-1443	PAD 05	100		Transient
FY2000	1/14/00	C-141 B	66-7952	PAD 05	525		Transient
FY2000	1/14/00			PAD 05	450		Ags
FY2000	1/14/00	KC-135 E	57-1443	PAD 05	25		Ags
FY2000	1/14/00	C-141 B	66-7952	PAD 05	150		Ags
FY2000	2/3/00	C-5 A	222	ECHO-4	260	260	Ags
FY2000	2/3/00	C-5 A	85-0003	PAD 23	600		Ags
FY2000	2/3/00	C-5 A	85-0003	PAD 23	100		Ags
FY2000	2/4/00			ECHO-8	100	100	Ags
FY2000	2/4/00			ECHO-8	20	20	Ags
FY2000	2/4/00			ECHO-8	50	50	Ags
FY2000	2/5/00			ECHO-2	50	50	Ags
FY2000	2/20/00	C-130 E	63-7826	TANGO @ ECHO 8	70	70	Ags
FY2000	2/26/00	C-5 A	211	ECHO-2	50	50	Ags
FY2000	3/7/00			PAD 05	100		Ags
FY2000	7/13/00				55		Fleet Svs
FY2000	7/26/00				165		Fleet Svs
FY2000	8/9/00				165		Fleet Svs
FY2000	8/25/00				110		Fleet Svs
FY2000	9/18/00				220		Fleet Svs
FY2001	10/6/00				165		Fleet Svs
FY2001	11/3/00				165		Fleet Svs
FY2001	12/1/00	KC-10	84-0188	ECHO-7	25	25	Transient
FY2001	12/1/00	C-130 H	91-9142	ECHO-15	15	15	Transient
FY2001	12/3/00	C-130 H	94-7312	ECHO-8	30	30	Transient
FY2001	12/4/00				135		Fleet Svs
FY2001	12/8/00	C-5 A	211	ECHO-1	160	160	Ags
FY2001	12/8/00	C-5 A	211	ECHO-1	300	300	Ags
FY2001	12/8/00	C-5 A	211	ECHO-1	200	200	Ags

APPENDIX C

WESTOVER AIR RESERVE BASE DEICING LOGS 1997 - 2003

					Deicing Fluid Used (Gallons)		
FY_Year	Date	Aircraft Type	Aircraft Tail #	Location Deiced	Facility	To Outfall 001	Remarks
FY2001	12/9/00	C-5 A	211	ECHO-1	240	240	Ags
FY2001	12/12/00	C-5 A	211 & 017	FUEL CELL & REAR ISO DCK	400		Ags
FY2001	1/2/01			ECHO-2 & 3	200	200	Ags
FY2001	1/2/01			REAR ISO DCK	25		Ags
FY2001	1/2/01			FUEL CELL	75		Ags
FY2001	1/4/01			ECHO-3	50	50	Ags
FY2001	1/5/01			ECHO-2	75	75	Ags
FY2001	1/9/01	A-10 A (2)	80-0171 80-0276	ECHO-8	40	40	Transient
FY2001	1/9/01			ECHO-3	100	100	Ags
FY2001	1/16/01	C-5 A	211	ECHO-1	25	25	Ags
FY2001	1/16/01	C-5 A	19	ECHO-5	40	40	Ags
FY2001	1/16/01			ECHO-5	220	220	Ags
FY2001	1/16/01	C-5 A	19	ECHO-4	200	200	Ags
FY2001	1/17/01				225		Fleet Svs
FY2001	1/18/01	KC-135R	62-3515	ECHO-8	200	200	Transient
FY2001	1/19/01			ECHO-2	100	100	Ags
FY2001	1/19/01			DC NORTH	100		Ags
FY2001	1/23/01			ECHO-4	20	20	Ags
FY2001	1/23/01	C-5 A	19	ECHO-6	50	50	Ags
FY2001	1/24/01	C-5A	211	ECHO-5	20	20	Ags
FY2001	2/9/01			ECHO-3	250	250	Ags
FY2001	2/16/01				275		Fleet Svs
FY2001	2/17/01	C-5 A	9003	FUEL CELL	400		Ags
FY2001	2/17/01	C-5 A	9003	FUEL CELL	200		Ags
FY2001	2/23/01	C-141 B	66-0192	ECHO-8	290	290	Transient
FY2001	3/18/01				250		Fleet Svs
FY2001	4/15/01				275		Fleet Svs
FY2001	5/9/01				250		Fleet Svs
FY2001	5/14/01			ECHO-12 -INFLD STORM DRAIN	50	50	Ags - Testing
FY2001	6/6/01				275		Fleet Svs
FY2001	7/15/01				165		Fleet Svs
FY2001	7/30/01				330		Fleet Svs
FY2001	8/31/01				165		Fleet Svs
FY2002	10/1/01				330		Fleet Svs
FY2002	11/1/01				150		Fleet Svs
FY2002	11/28/01				300		Fleet Svs
FY2002	12/7/01				165		Fleet Svs
FY2002	12/9/01	C-26 B	91-0513	NORTH RAMP	115		Transient
FY2002	12/9/01	C-130 H	81-0628	ECHO-15	245	245	Transient
FY2002	12/9/01	F/A-18D	163436	ECHO-16	125	125	Transient
FY2002	12/9/01	C-130 E	64-0539	NORTH RAMP	275		Transient
FY2002	12/9/01	C-130 E	70-1265	NORTH RAMP	400		Transient
FY2002	12/9/01	C-130 E	64-0499	NORTH RAMP	365		Transient
FY2002	12/9/01	C-130 E	70-1263	NORTH RAMP	350		Transient
FY2002	12/9/01	C-130 E	64-0570	NORTH RAMP	365		Transient
FY2002	12/9/01	C-130 E	64-0540	NORTH RAMP	300		Transient
FY2002	12/9/01	C-130s	VARIOUS	NORTH RAMP	380		Ags
FY2002	12/10/01			ECHO-3	100	100	Ags
FY2002	12/23/01	C-130 H	92-3286	ECHO-15	15	15	Transient
FY2002	12/27/01	C-130 E	64-0540	ECHO-15	25	25	Transient
FY2002	1/9/02			ECHO-3	200	200	Ags
FY2002	1/9/02			ECHO-3	300	300	Ags
FY2002	1/9/02			ECHO-3	100	100	Ags
FY2002	1/9/02			ECHO-3	80	80	Ags
FY2002	1/9/02	C-5A	9003	ECHO-3	500	500	Ags
FY2002	1/14/02				275		Fleet Svs
FY2002	1/17/02	C-130 H	81-0629	ECHO-15	60	60	Transient
FY2002	1/17/02			ECHO-4	80	80	Ags
FY2002	1/17/02			ECHO-5	150	150	Ags
FY2002	1/20/02	KC-10 A	79-1713	ECHO-7	845	845	Transient
FY2002	1/20/02	KC-10 A	97	ECHO-7	35	35	Ags
FY2002	2/2/02	C-5A	90017	ECHO-2	800	800	Ags
FY2002	2/5/02				240		Fleet Svs
FY2002	2/17/02	C-130 H	74-1665	ECHO-15	20	20	Transient
FY2002	2/27/02	C-130	64-0539	NORTH RAMP	75		Transient
FY2002	2/27/02	C-130 E	64-0539	NORTH RAMP	75		Ags
FY2002	3/4/02				325		Fleet Svs
FY2002	3/18/02	C-130 H, C-130 E, A-10	92-3022 70-1235 NONE	ECHO-6, ECHO-7 ECHO-16	410	410	Ags
FY2002	3/18/02			NORTH RAMP N-9, N-8 & N-7	195		Ags
FY2002	3/21/02	C-5A	8211	ECHO-1	1,000	1,000	Ags
FY2002	3/21/02			NORTH RAMP N-4	250		Ags
FY2002	3/21/02			ECHO-1	250	250	Ags
FY2002	3/21/02	C-5A	68-222	ECHO-4	800	800	Ags
FY2002	3/21/02	C-5A	68-222	ECHO-4	1,000	1,000	Ags
FY2002	3/25/02				165		Fleet Svs
FY2002	3/31/02				165		Fleet Svs
FY2002	5/6/02				330		Fleet Svs
FY2002	5/30/02				280		Fleet Svs
FY2002	6/20/02				330		Fleet Svs
FY2002	7/2/02				130		Fleet Svs
FY2002	7/9/02				135		Fleet Svs
FY2002	7/22/02				165		Fleet Svs
FY2002	7/30/02				165		Fleet Svs
FY2002	8/8/02				285		Fleet Svs
FY2002	8/26/02				235		Fleet Svs

APPENDIX C

WESTOVER AIR RESERVE BASE DEICING LOGS 1997 - 2003

FY_Year	Date	Aircraft Type	Aircraft Tail #	Location Deiced	Deicing Fluid Used (Gallons) Facility	To Outfall 001	Remarks
FY2002	9/13/02				275		Fleet Svs
FY2003	10/2/02				165		Fleet Svs.
FY2003	10/22/02				275		Fleet Svs.
FY2003	10/25/02	C-5 A	9011	ECHO-4	100		Ags
FY2003	10/25/02	C-5 A	9011	ECHO-4	50	50	Ags
FY2003	11/13/02				165		Fleet Svs.
FY2003	11/16/02	C-5 A	700447	ECHO-9	250		Ags
FY2003	11/16/02	C-5 A	700447	ECHO-9	250		Ags
FY2003	11/17/02	C-5 A	700447	ECHO-9	250		Ags
FY2003	11/18/02	C130 H	VARIOUS	NORTH 4 & 5	155		Transient
FY2003	11/18/02	C-5 A	86-0019	ECHO-9	70		Ags
FY2003	11/19/02	C-5 A	80-0211	ECHO-8	150		Ags
FY2003	11/20/02				165		Fleet Svs.
FY2003	11/27/02	E C130E	73-1588	ECHO-16	150	150	Transient
FY2003	11/29/02	C-5 A	90-022	DC NORTH - FUEL CELL	100		Ags
FY2003	11/29/02	C-5 A	90-022	DC NORTH - FUEL CELL	75		Ags
FY2003	11/30/02	C-5 A	8225	DC NORTH - FUEL CELL	80		Ags
FY2003	12/3/02	C-5 A	304	DC NORTH - FUEL CELL	350		Ags
FY2003	12/5/02	C-5 A	9017	ECHO-7	125	125	Ags
FY2003	12/5/02		86-0022	PAD 23	350		Ags
FY2003	12/5/02		86-0022	PAD 23	500		Ags
FY2003	12/5/02		86-0022	PAD 23	250		Ags
FY2003	12/6/02		7167	ECHO-6	200	200	Ags
FY2003	12/6/02		8225	ECHO-3	500	500	Ags
FY2003	12/6/02		8225	ECHO-3	1,400	1,400	Ags
FY2003	12/8/02	C-5 A	9019	ECHO-13	150	150	Ags
FY2003	12/8/02	C-5 A	8215	ECHO-11	300		Ags
FY2003	12/10/02				330		Fleet Svs.
FY2003	12/12/02	C-5 A	9017 & 8225	ECHO-2 & 6	800	800	Ags
FY2003	12/12/02	C-5 A	9017	ECHO-2	400	400	Ags
FY2003	12/12/02	C-5 A	9017	ECHO-2	600	600	Ags
FY2003	12/12/02	C-5 A	219	ECHO-1	50	50	Ags
FY2003	12/12/02	C-5 A	8225	ECHO-6	400	400	Ags
FY2003	12/13/02	C-5 A	8225	ECHO-6	50	50	Ags
FY2003	12/16/02	C-5 A	167	ECHO-5	250	250	Ags
FY2003	12/16/02	C-5 A	167	ECHO-5	310	310	Ags
FY2003	12/16/02	C-5 A	219	ECHO-1	500	500	Ags
FY2003	12/16/02	C-5 A	9011	ECHO-7	800	800	Ags
FY2003	12/16/02	C-5 A	9011	ECHO-7	800	800	Ags
FY2003	12/16/02	C-5 A	219	ECHO-1	500	500	Ags
FY2003	12/17/02	C-5 A	9022	ECHO-3	400	400	Ags
FY2003	12/17/02	C-5 A	9022	ECHO-3	400	400	Ags
FY2003	12/17/02	C-5 A	167	ECHO-5	300	300	Ags
FY2003	12/18/02	C-5 A	9017	ECHO-13	185	185	Ags
FY2003	12/26/02	C-5 A	9011	DC NORTH FUEL CELL	500		Ags
FY2003	12/27/02	C-5 A	67-00167	DC NORTH FUEL CELL	200		Ags
FY2003	12/29/02				250		Fleet Svs.
FY2003	1/2/03	C-5 A	67-00167	DC NORTH FUEL CELL	350		Ags
FY2003	1/2/03	C-5 A	67-00167	DC NORTH FUEL CELL	500		Ags
FY2003	1/2/03	C-5 A	67-00167	DC NORTH FUEL CELL	400		Ags
FY2003	1/6/03	C-130 H	74-1667	ECHO-16	245	245	Transient
FY2003	1/7/03	C-5 A	8222	DC NORTH FUEL CELL	250		Ags
FY2003	1/26/03				275		Fleet Svs.
FY2003	1/27/03	C-5 A	8225	DC NORTH FUEL CELL	300		Ags
FY2003	1/28/03	C-5 A	69-017	ECHO-6	650	650	Ags
FY2003	1/28/03	C-5 A	8215	ECHO-2	300	300	Ags
FY2003	1/29/03	C-5 A	8219	ECHO-1	300	300	Ags
FY2003	1/31/03	C-5 A	17	ECHO-6	75	75	Ags
FY2003	1/31/03	C-5 A	8222	ECHO-5	75	75	Ags
FY2003	2/1/03	C-130 H	94-7320	ECHO-8	50	50	Transient
FY2003	2/1/03	C-5 A	17	ECHO-2	225	225	Ags
FY2003	2/1/03	C-5 A	448	ECHO-3	225	225	Ags
FY2003	2/1/03	C-5 A	448	ECHO-2	150	150	Ags
FY2003	2/1/03	C-5 A	17	ECHO-3	150	150	Ags
FY2003	2/2/03	C-130 H	94-7320	ECHO-8	120	120	Transient
FY2003	2/3/03				160		Fleet Svs.
FY2003	2/6/03				165		Fleet Svs.
FY2003	2/7/03	C-5 A	9013	ECHO-9	250		Ags
FY2003	2/7/03	C-5 A	9013	ECHO-9	400		Ags
FY2003	2/7/03	C-5 A	9013	ECHO-9	205		Ags
FY2003	2/7/03	C-5 A	8	ECHO-6	205	205	Ags
FY2003	2/7/03	C-5 A	9011	ECHO-6	335	335	Ags
FY2003	2/7/03	C-5 A	8	ECHO-5	835	835	Ags
FY2003	2/7/03	C-5 A	70-459	ECHO-2	235	235	Ags
FY2003	2/7/03	C-5 A	10	ECHO-1	410	410	Ags
FY2003	2/7/03	C-5 A		ECHO-9	500		Ags
FY2003	2/7/03	C-5 A		ECHO-4	800	800	Ags
FY2003	2/7/03	C-5 A	9011	ECHO-5	430	430	Ags
FY2003	2/7/03	C-5 A	9011	ECHO-5	200	200	Ags
FY2003	2/7/03	C-5 A	9011	ECHO-5	835	835	Ags
FY2003	2/7/03	C-5 A	8	ECHO-5	835	835	Ags
FY2003	2/7/03	C-5 A	219	ECHO-10	230		Ags
FY2003	2/7/03	C-5 A	459	ECHO-4	225	225	Ags
FY2003	2/7/03	C-5 A	22	ECHO-2	115	115	Ags
FY2003	2/7/03	C-5 A	13	ECHO-9	750		Ags

APPENDIX C

WESTOVER AIR RESERVE BASE DEICING LOGS 1997 - 2003

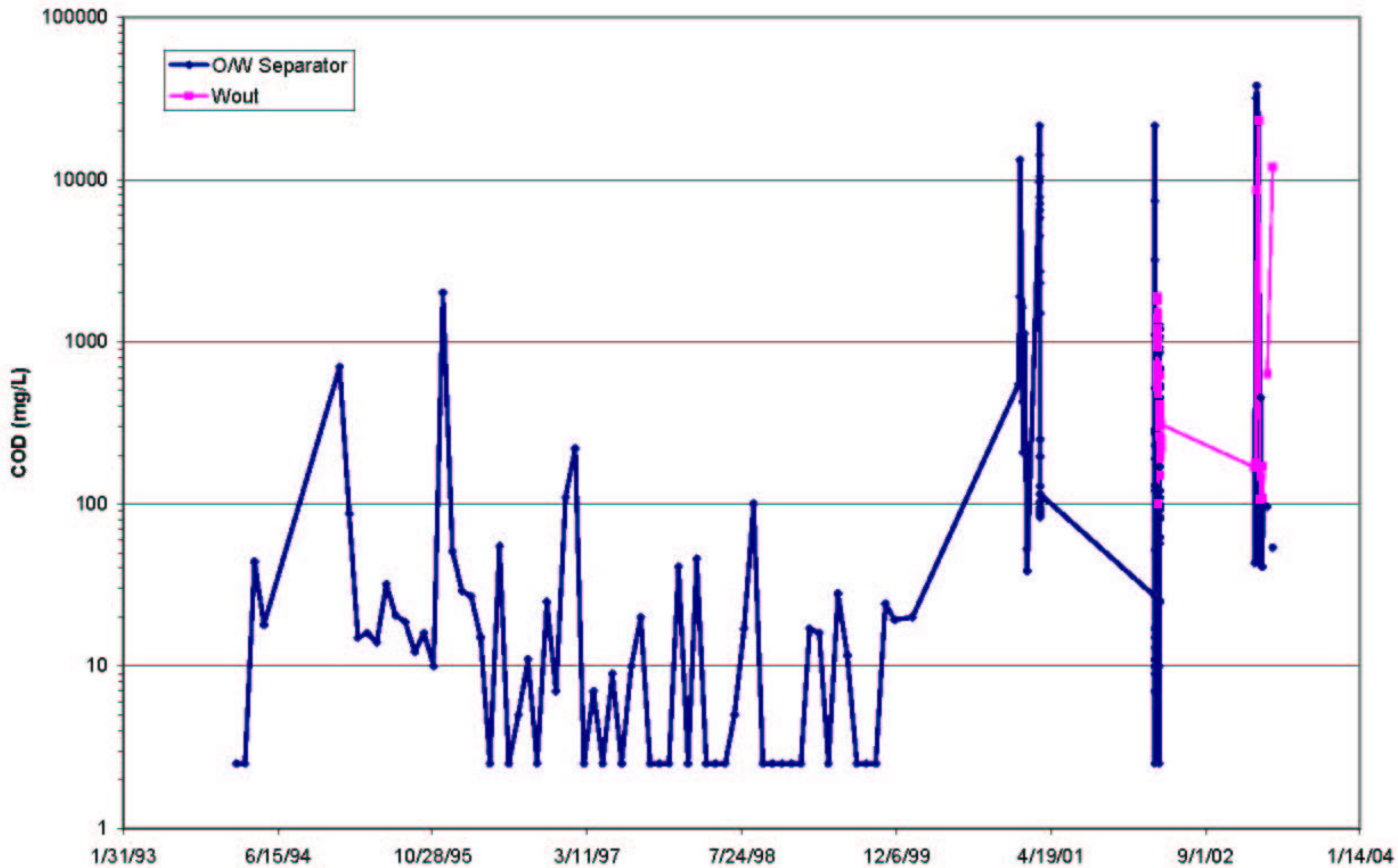
					Deicing Fluid Used (Gallons)		
FY_Year	Date	Aircraft Type	Aircraft Tail #	Location Deiced	Facility	To Outfall 001	Remarks
FY2003	2/7/03	C-5 A	459	ECHO-3	150	150	Ags
FY2003	2/7/03	C-141	8	ECHO-5	225	225	Transient
FY2003	2/7/03	C-9 A	68-10958	ECHO-8	250	250	Transient
FY2003	2/7/03	C-5 A	459	DC NORTH FUEL CELL	200		Ags
FY2003	2/9/03				165		Fleet Svs.
FY2003	2/9/03	C-5 A	17	DC NORTH FUEL CELL	100		Ags
FY2003	2/10/03	C-130 E	69-6582	ECHO-7	50	50	Transient
FY2003	2/10/03	C-5 A	69-0006	ECHO-5	800	800	Ags
FY2003	2/10/03	C-5 A	69-0006	ECHO-5	100	100	Ags
FY2003	2/10/03	C-130 E	69-6582	ECHO-8	500	500	Ags
FY2003	2/11/03	C-5 A	69-0006	ECHO-5	200	200	Ags
FY2003	2/11/03	C-5 A	7167	ECHO-6	200	200	Ags
FY2003	2/11/03	C-5 A	1285	ECHO-3	200	200	Ags
FY2003	2/11/03	C-5 A	7028	ECHO-7	200	200	Ags
FY2003	2/11/03	C-5 A		ECHO-8	200	200	Ags
FY2003	2/11/03	C-5 A		ECHO-7	200	200	Ags
FY2003	2/11/03	C-5 A		ECHO-9	200		Ags
FY2003	2/12/03	C-5 A	167	ECHO-6	800	800	Ags
FY2003	2/12/03	C-5 A	463	ECHO-5	150	150	Ags
FY2003	2/12/03	C-5 A	22	ECHO-7	150	150	Ags
FY2003	2/12/03	C-5 A	22	ECHO-9	150		Ags
FY2003	2/12/03	C-5 A	463	ECHO-4	750	750	Ags
FY2003	2/12/03	C-5 A	22	ECHO-9	660		Ags
FY2003	2/12/03	MC-130 E	64-0551	ECHO-8	80	80	Transient
FY2003	2/12/03	WC-130 J	97-5303	ECHO-15	140	140	Transient
FY2003	2/14/03				165		Fleet Svs.
FY2003	2/17/03	C-5 A		ECHO-2	275	275	Ags
FY2003	2/17/03	C-5 A		ECHO-4	275	275	Ags
FY2003	2/17/03	C-5 A		ECHO-7	285	285	Ags
FY2003	2/17/03	C-5 A		ECHO-6	175	175	Ags
FY2003	2/17/03	C-5 A		ECHO-11	175		Ags
FY2003	2/17/03	C-5 A		ECHO-12	185	185	Ags
FY2003	2/18/03				310		Fleet Svs.
FY2003	2/18/03	C-9 A	68-10958	BASE HGR	50		Transient
FY2003	2/18/03	C-5 A	9019	ECHO-11	250		Ags
FY2003	2/18/03	C-5 A	TRAN	ECHO-4	250	250	Ags
FY2003	2/18/03	C-5 A	222	ECHO-12	275	275	Ags
FY2003	2/18/03	C-5 A	451	ECHO-13	275	275	Ags
FY2003	2/18/03	C-5 A	9030	ECHO-12	450	450	Ags
FY2003	2/18/03	C-5 A	30	ECHO-12	100	100	Ags
FY2003	2/18/03	C-5 A	451	ECHO-12	100	100	Ags
FY2003	2/18/03	C-5 A	11	ECHO-1	350	350	Ags
FY2003	2/18/03	C-5 A	9011	ECHO-1	500	500	Ags
FY2003	2/18/03	C-5 A	9003	ECHO-14	300	300	Ags
FY2003	2/19/03	C-5 A	9019	ECHO-3	800	800	Ags
FY2003	2/19/03	C-5 A	448	ECHO-1	800	800	Ags
FY2003	2/24/03	C-5 A	60015	ECHO-5	500	500	Ags
FY2003	2/24/03	C-5 A	6	ECHO-12	200	200	Ags
FY2003	3/1/03	C-5 A	870041	ECHO-5	25	25	Ags
FY2003	3/1/03	C-5 A	870029	ECHO-6	50	50	Ags
FY2003	3/1/03	C-5 A	9011	ECHO-9	25		Ags
FY2003	3/1/03	C-5 A	41	ECHO-3	500	500	Ags
FY2003	3/1/03	C-5 A	29	ECHO-4	100	100	Ags
FY2003	3/1/03	C-5 A	11	ECHO-9	100		Ags
FY2003	3/2/03	C-5 A	29	ECHO-4	350	350	Ags
FY2003	3/2/03	C-5 A	11	ECHO-9	300		Ags
FY2003	3/6/03	C-5 A	87-0031	ECHO-3	900	900	Ags
FY2003	3/6/03	C-5 A	6171	ECHO-12	605	605	Ags
FY2003	3/6/03	C-5 A	31	ECHO-3	460	460	Ags
FY2003	3/6/03	C-5 A	85-008	NORTH-1	435		Ags
FY2003	3/6/03	C-5 A	85-008	HOT SPOT #2	335		Ags
FY2003	3/6/03	C-5 A	870171	ECHO-7	400	400	Ags
FY2003	3/7/03	C-5 A	90019	ECHO-3	835	835	Ags
FY2003	3/7/03	C-5 A	90019	ECHO-3	835	835	Ags
FY2003	3/7/03	C-5 A	90019	ECHO-3	600	600	Ags
FY2003	3/7/03	C-5 A	800219	ECHO-11	250		Ags
FY2003	3/7/03	C-5 A	870171	ECHO-7	645	645	Ags
FY2003	3/7/03	C-5 A	85008	HOT SPOT #2	350		Ags
FY2003	3/7/03	C-5 A	61	ECHO-8	485	485	Ags
FY2003	3/7/03	C-5 A	61	ECHO-8	450	450	Ags
FY2003	3/7/03	C-5 A	870171	ECHO-7	635	635	Ags
FY2003	3/7/03	C-5 A	006	ECHO-10	75		Ags
FY2003	3/7/03	C-5 A	006	ECHO-5	75	75	Ags
FY2003	3/13/03	C-5 A	70-448	ECHO-15	350	350	Ags
FY2003	3/13/03	C-5 A	68-223	ECHO-11	600		Ags
FY2003	3/13/03	C-5 A	167	ECHO-4	600	600	Ags
FY2003	3/13/03	C-5 A	041	ECHO-7	85	85	Ags
FY2003	3/13/03	C-5 A	041	ECHO-7	1,000	1,000	Ags
FY2003	3/14/03	C-5 A	304	ECHO-15	150	150	Ags
FY2003	3/14/03	C-5 A	003	ECHO-14	150	150	Ags
FY2003	3/14/03	C-5 A	015	ECH0-13	150	150	Ags
FY2003	3/14/03	C-5 A	015	ECHO-13	260	260	Ags
FY2003	3/14/03	C-5 A	167	ECHO-1	260	260	Ags
FY2003	3/14/03	C-5 A	9019	NORTH-2	500		Ags
FY2003	3/14/03	C-5 A	014	ECHO-12	150	150	Ags

APPENDIX C

WESTOVER AIR RESERVE BASE DEICING LOGS 1997 - 2003

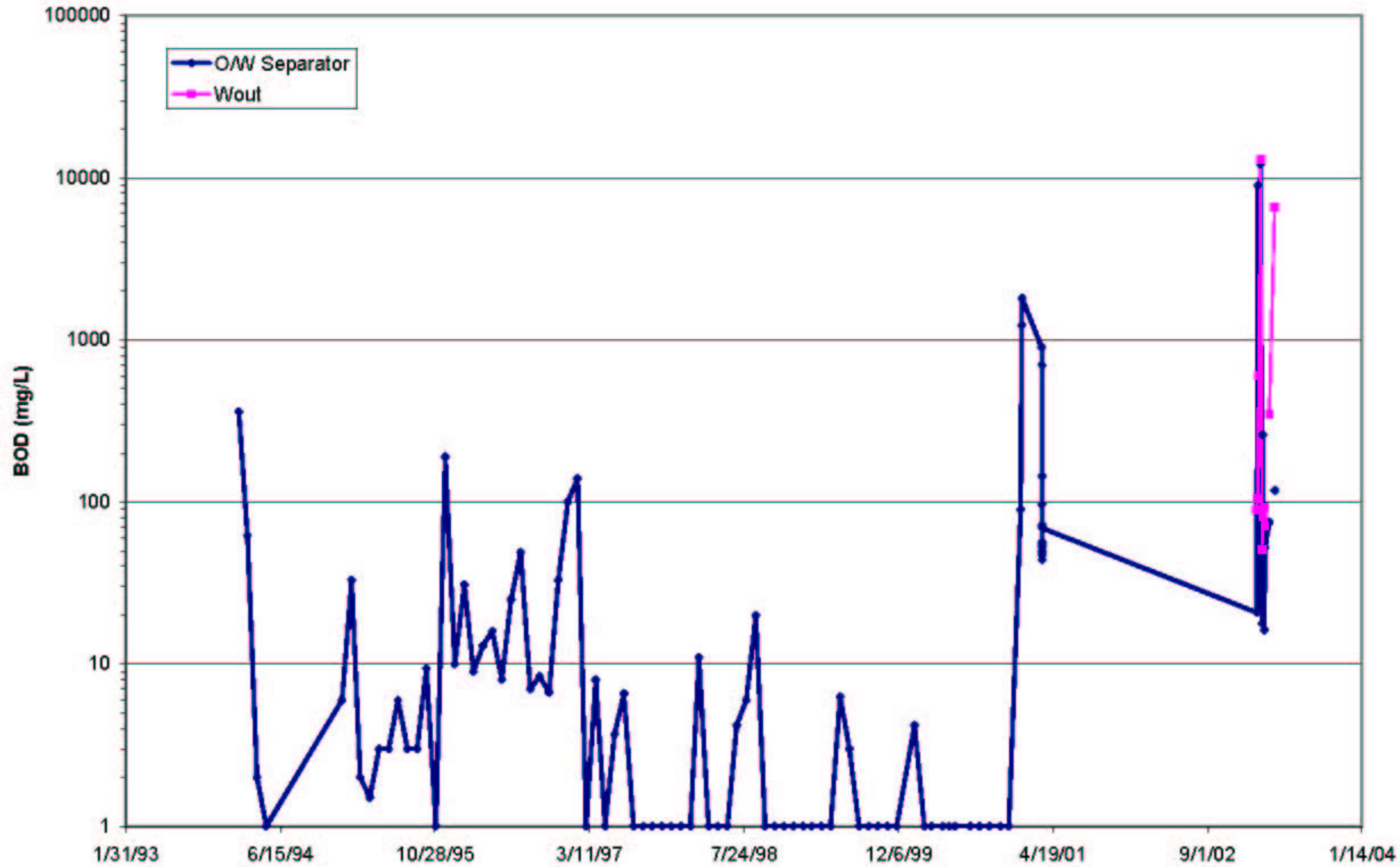
					Deicing Fluid Used (Gallons)		
FY_Year	Date	Aircraft Type	Aircraft Tail #	Location Deiced	Facility	To Outfall 001	Remarks
FY2003	3/14/03	C-5 A	014	ECHO-14	150	150	Ags
FY2003	3/14/03	C-5 A	167	POINT S	50		Ags
FY2003	3/14/03	C-5 A	019	NORTH-2	500		Ags
FY2003	3/14/03	C-5 A	019	NORTH-2	180		Ags
FY2003	3/14/03	C-5 A	019	NORTH-2	150		Ags
FY2003	3/15/03	C-5 A	70-448	ECHO-15	500	500	Ags
FY2003	3/15/03	C-5 A	69-007	ECHO-14	500	500	Ags
FY2003	3/30/03	C-5 A	7033	ECHO-8	225	225	Ags
FY2003	3/30/03	C-5 A	5006	ECHO-7	300	300	Ags
FY2003	3/30/03	C-5 A	5006	ECHO-11	200		Ags
FY2003	3/30/03	C-5 A	7034	ECHO-7	100	100	Ags
FY2003	3/30/03	C-5 A	7034	ECHO-11	300		Ags
FY2003	3/31/03	C-5 A	50002	ECHO-4	500	500	Ags
FY2003	3/31/03	C-5 A	50002	ECHO-4	430	430	Ags
FY2003	4/1/03	C-17 A	00-0173	NORTH-4	100		Transient
FY2003	4/1/03	KC-135R	59-1458	BASE HANGAR	30		Transient
FY2003	4/1/03	KC-135R	59-1458	BASE HANGAR	100		Ags
FY2003	4/1/03	C-5 A	86-00021	ECHO-5	200	200	Ags
FY2003	4/2/03	C-5 A	69-004	HOT SPOT #1	500		Ags
FY2003	4/2/03	C-5 A	0035	ECHO-12	240	240	Ags
FY2003	4/2/03	C-5 A	6012	ECHO-10	250	250	Ags
FY2003	4/4/03	C-17 A	00172	NORTH-1	450		Transient
FY2003	4/5/03	C-5 A	451	ECHO-10	200		Ags
FY2003	4/5/03	C-5 A	005	NORTH-1	400		Ags
FY2003	4/5/03	C-5 A	7170	ECHO-5	700	700	Ags
FY2003	4/5/03	C-5 A	030	ECHO-1	600	600	Ags
FY2003	4/5/03	C-5 A	030	ECHO-7	600	600	Ags
FY2003	4/5/03	C-5 A	211	ECHO-3	100	100	Ags
FY2003	4/5/03	C-5 A	211	ECHO-4	100	100	Ags
FY2003	4/5/03	C-5 A	451	ECHO-10	50		Ags
FY2003	4/5/03	C-5 A	007	ECHO-14	50	50	Ags
FY2003	4/5/03	C-5 A	0002	ECHO-2	700	700	Ags
FY2003	4/5/03	C-5A	5005	NORTH-1	400		Ags
FY2003	4/5/03	C-5A	8211	ECHO-3	100	100	Ags
FY2003	4/5/03	C-5A	7029	ECHO-1	750	750	Ags
FY2003	4/5/03	C-5A	5007	ECHO-9	70		Ags
FY2003	4/5/03	C-5A	170	ECHO-4	150	150	Ags
FY2003	4/5/03	C-5A	6014	ECHO-10	530		Ags
FY2003	4/5/03	C-5A		ECHO-9	250		Ags
FY2003	4/5/03	C-5A		NORTH-2	250		Ags
FY2003	4/5/03	C-5A		NORTH-3	100		Ags
FY2003	4/6/03	C-5A		ECHO-2	200	200	Ags
FY2003	4/6/03	C-5A		ECHO-6	150	150	Ags
FY2003	4/6/03	C-5A		ECHO-4	150	250	Ags
FY2003	4/7/03	C-5A	9010	ECHO-14	125	125	Ags
FY2003	4/8/03	C-5A	6031	ECHO-13	250	250	Ags
FY2003	4/8/03	C-5A		ECHO-8	700	700	Ags
FY2003	4/8/03	C-5A		ECHO-10	700		Ags
FY2003	4/8/03	C-5A		ECHO-11	700		Ags
FY2003	4/8/03	C-5A		ECHO-8	700	700	Ags
FY2003	4/8/03	C-5A		ECHO-10	700		Ags
FY2003	4/8/03	C-5A		ECHO-11	800		Ags
FY2003	4/8/03	C-5A	68-222	ECHO-8	500	500	Ags
FY2003	4/8/03	C-5A	69-211	ECHO-11	200		Ags
FY2003	4/8/03	C-5A	69-017	ECHO-10	300		Ags
FY2003	4/8/03	C-5A	448	ECHO-1	400	400	Ags
FY2003	4/8/03	C-5A	70060	ECHO-8	700	700	Ags
FY2003	4/8/03	C-5A	211	ECHO-10	650		Ags
FY2003	4/8/03	C-5A	222	ECHO-8	425	425	Ags
FY2003	4/8/03	C-5A	211	ECHO-10	425		Ags
FY2003	4/9/03	C-9A	88934	ECHO-16	20	20	Transient
TOTALS							
			FY1998		2,655		
			FY1999		8,175	2,210	
			FY2000		3,715	600	
			FY2001		6,775	2,900	
			FY2002		14,730	7,140	
			FY2003		76,150	51,555	
			FY1998 - 2003		112,200	64,405	

Appendix D
Time Series Plots



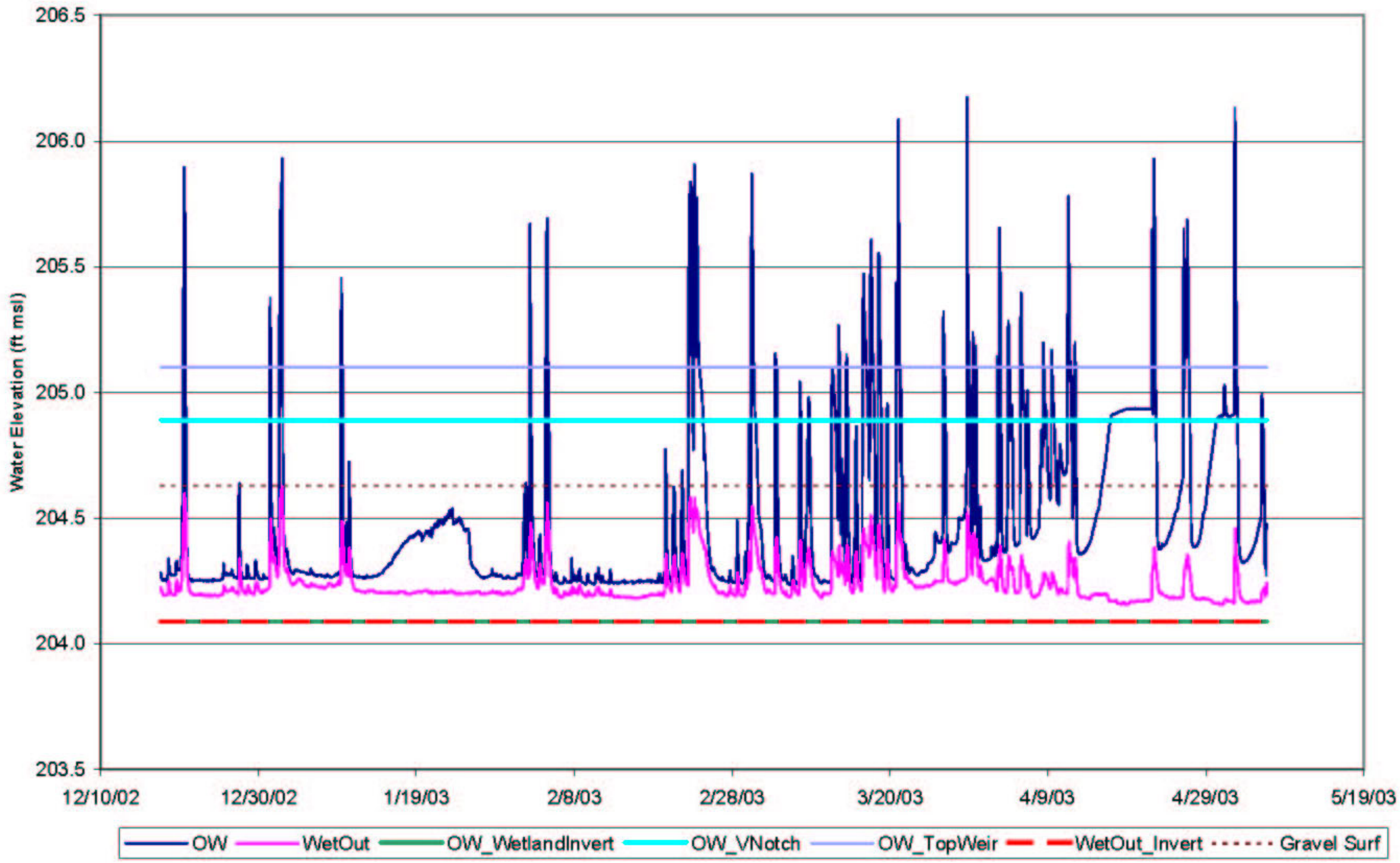
APPENDIX D

COD Measurements at the Outfall 001 Oil/Water Separator and Wetland Outflow, Westover Air Force Reserve Base, Chicopee, MA



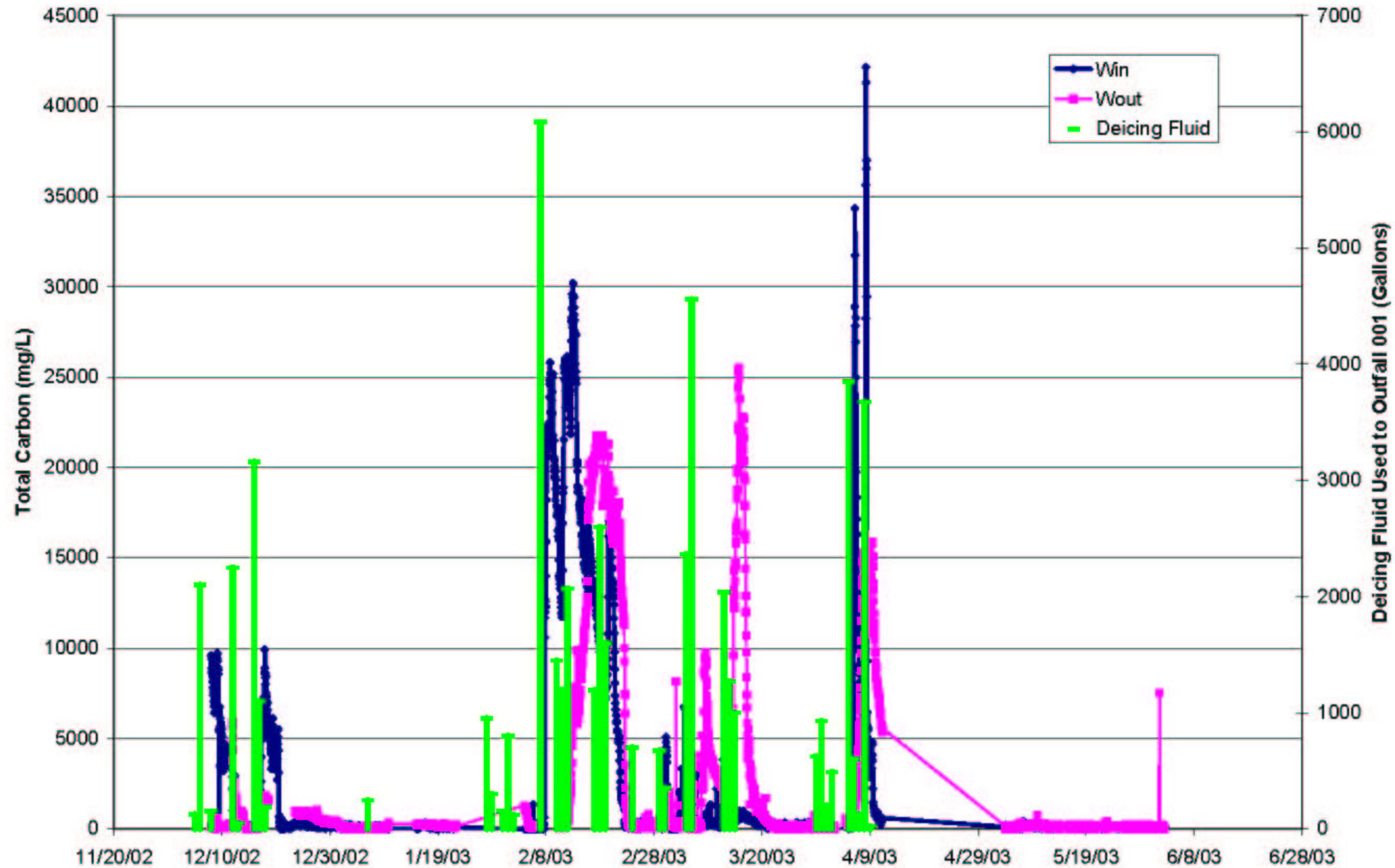
APPENDIX D

BOD Measurements at the Outfall 001 Oil/Water Separator and Wetland Outflow, Westover Air Force Reserve Base, Chicopee, MA



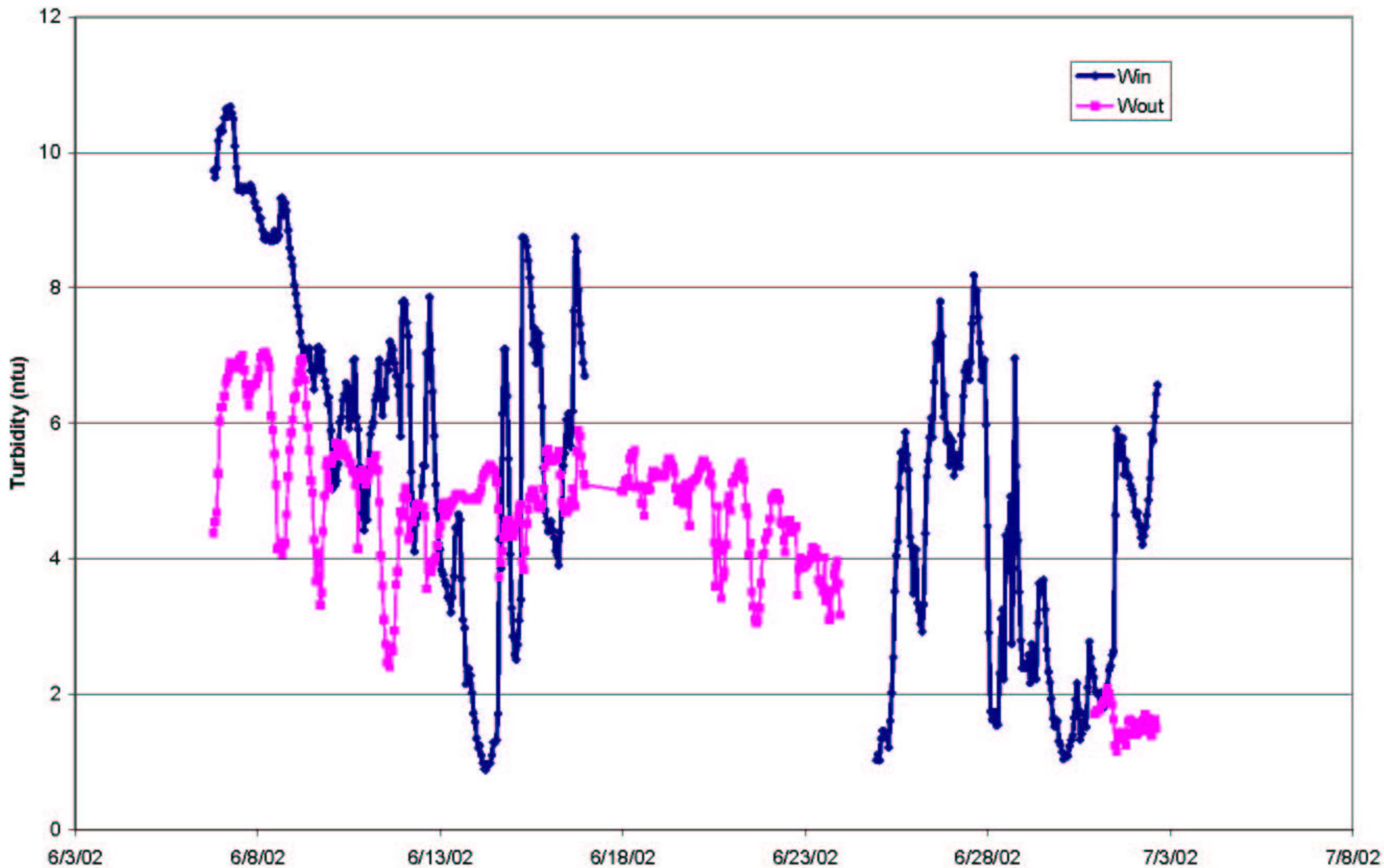
APPENDIX D

Water Elevations at the Outfall 001 Oil/Water Separator and Wetland Outflow, Westover Air Force Reserve Base, Chicopee, MA



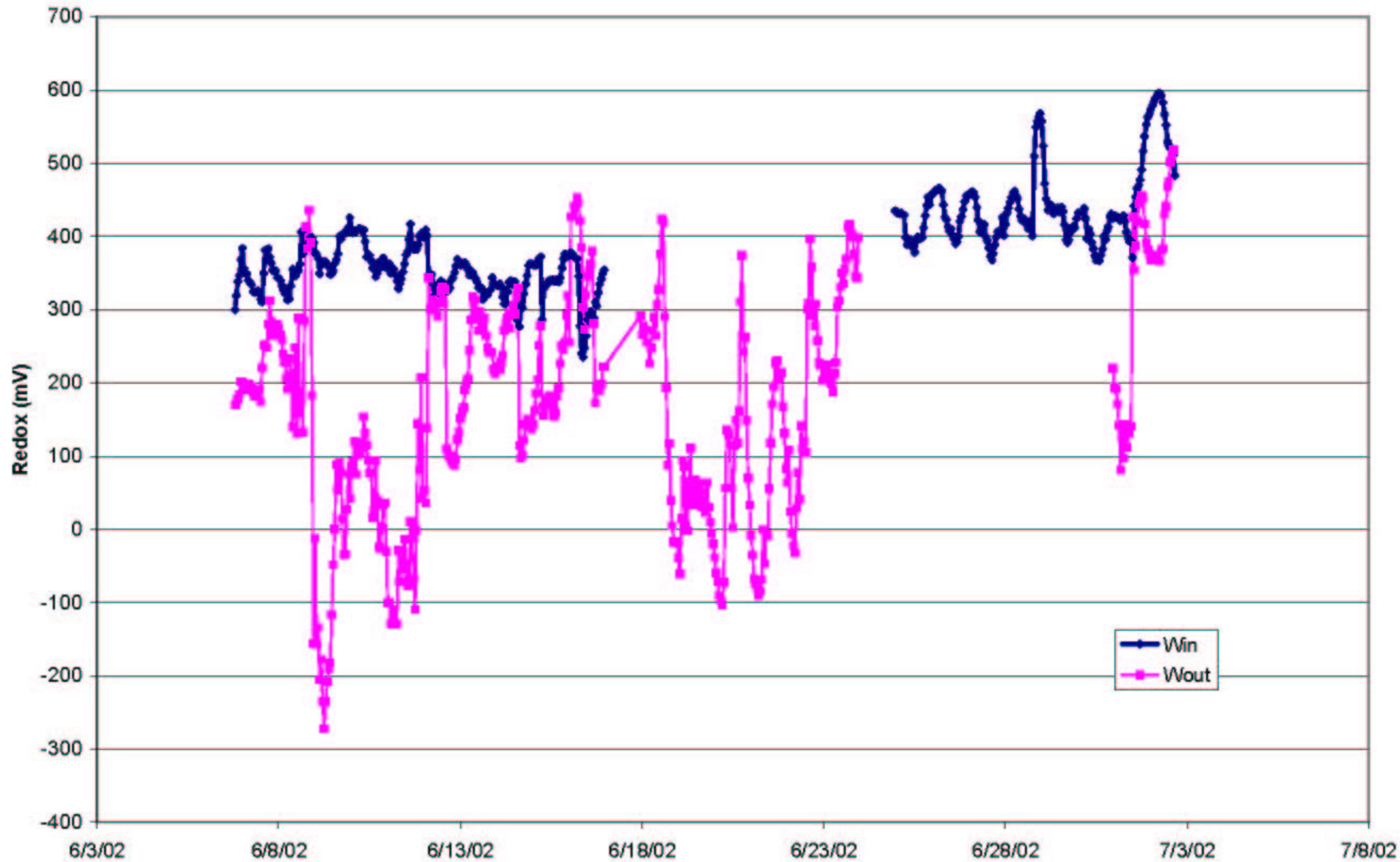
APPENDIX D

LAR Total Carbon Measurements at the Outfall 001 Oil/Water Separator and Wetland Outflow, Westover Air Force Reserve Base, Chicopee, MA



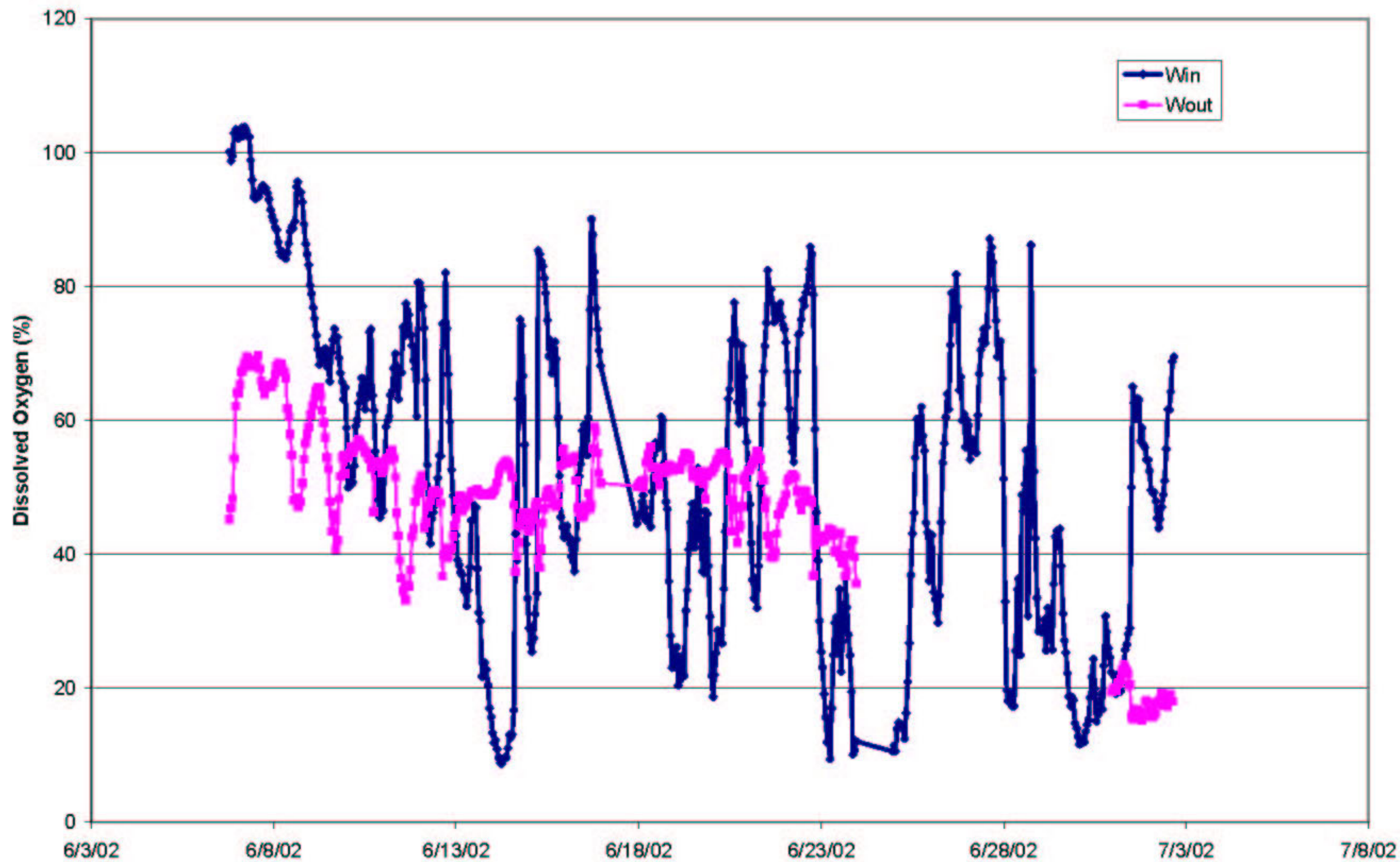
APPENDIX D

Turbidity Measurements at the Outfall 001 Oil/Water Separator and Wetland Outflow, Westover Air Force Reserve Base, Chicopee, MA



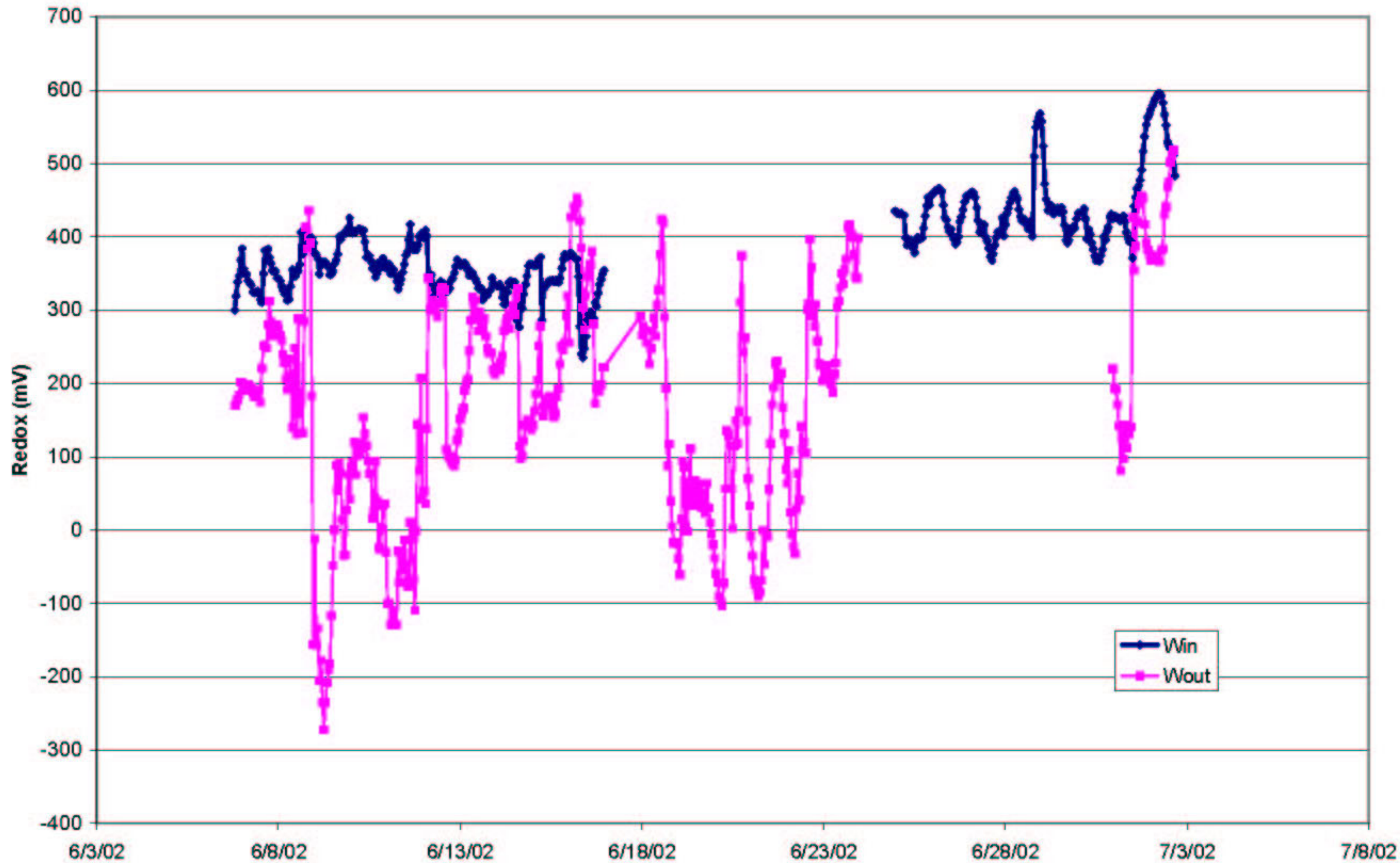
APPENDIX D

Redox Measurements at the Outfall 001 Oil/Water Separator and Wetland Outflow, Westover Air Force Reserve Base, Chicopee, MA



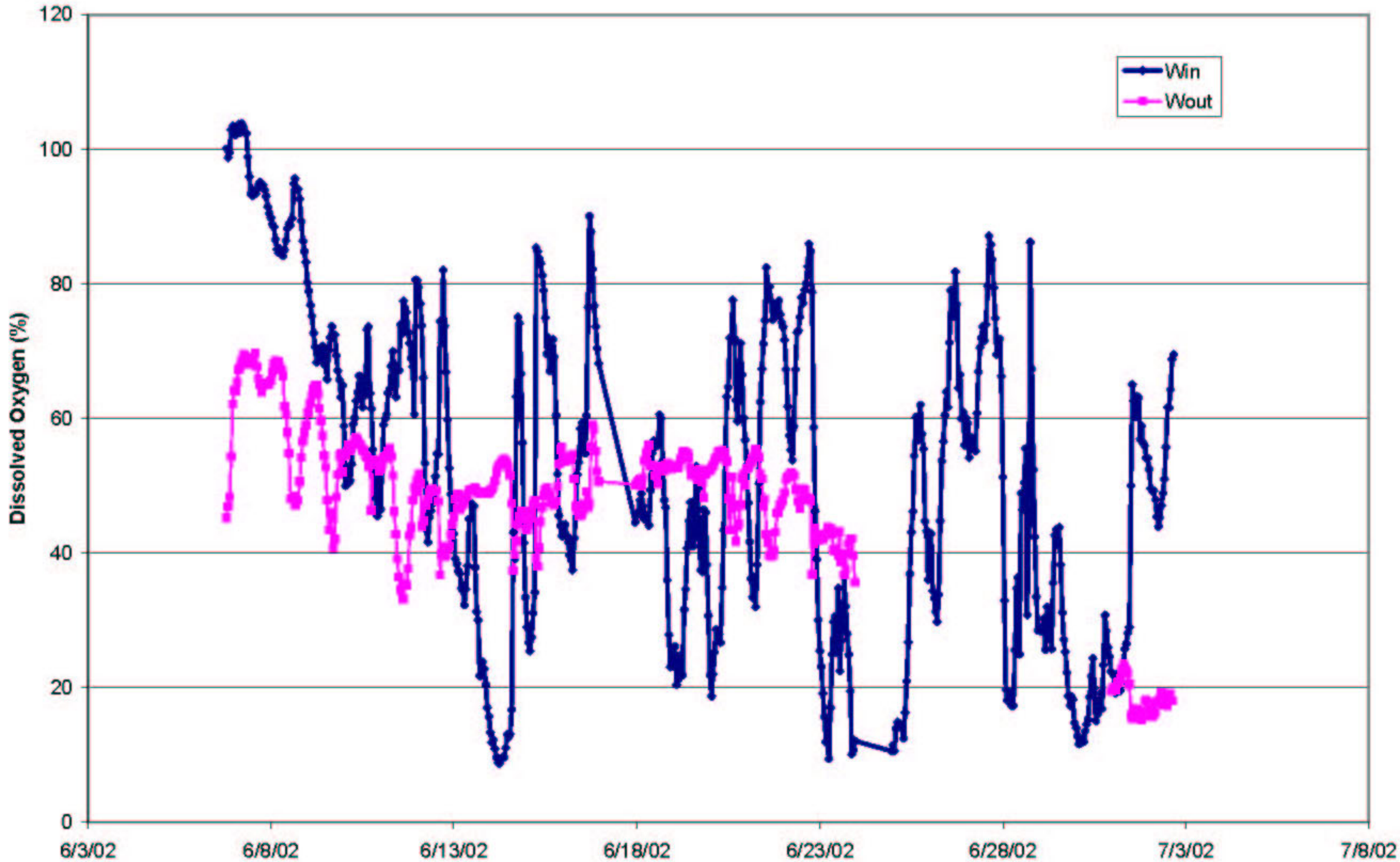
APPENDIX D

Dissolved Oxygen Measurements at the Outfall 001 Oil/Water Separator and Wetland Outflow, Westover Air Force Reserve Base, Chicopee, MA



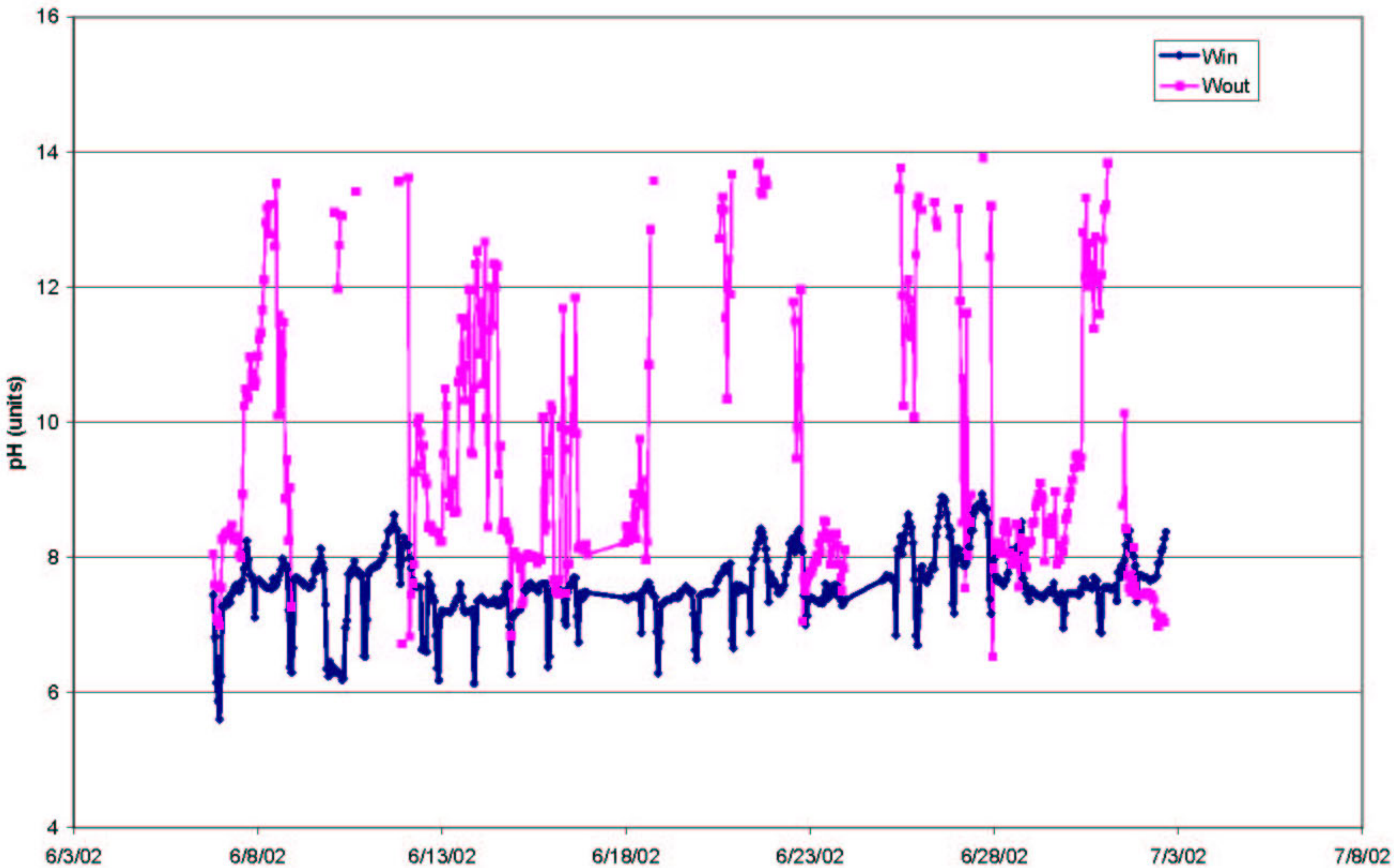
APPENDIX D

Redox Measurements at the Outfall 001 Oil/Water Separator and Wetland Outflow, Westover Air Force Reserve Base, Chicopee, MA



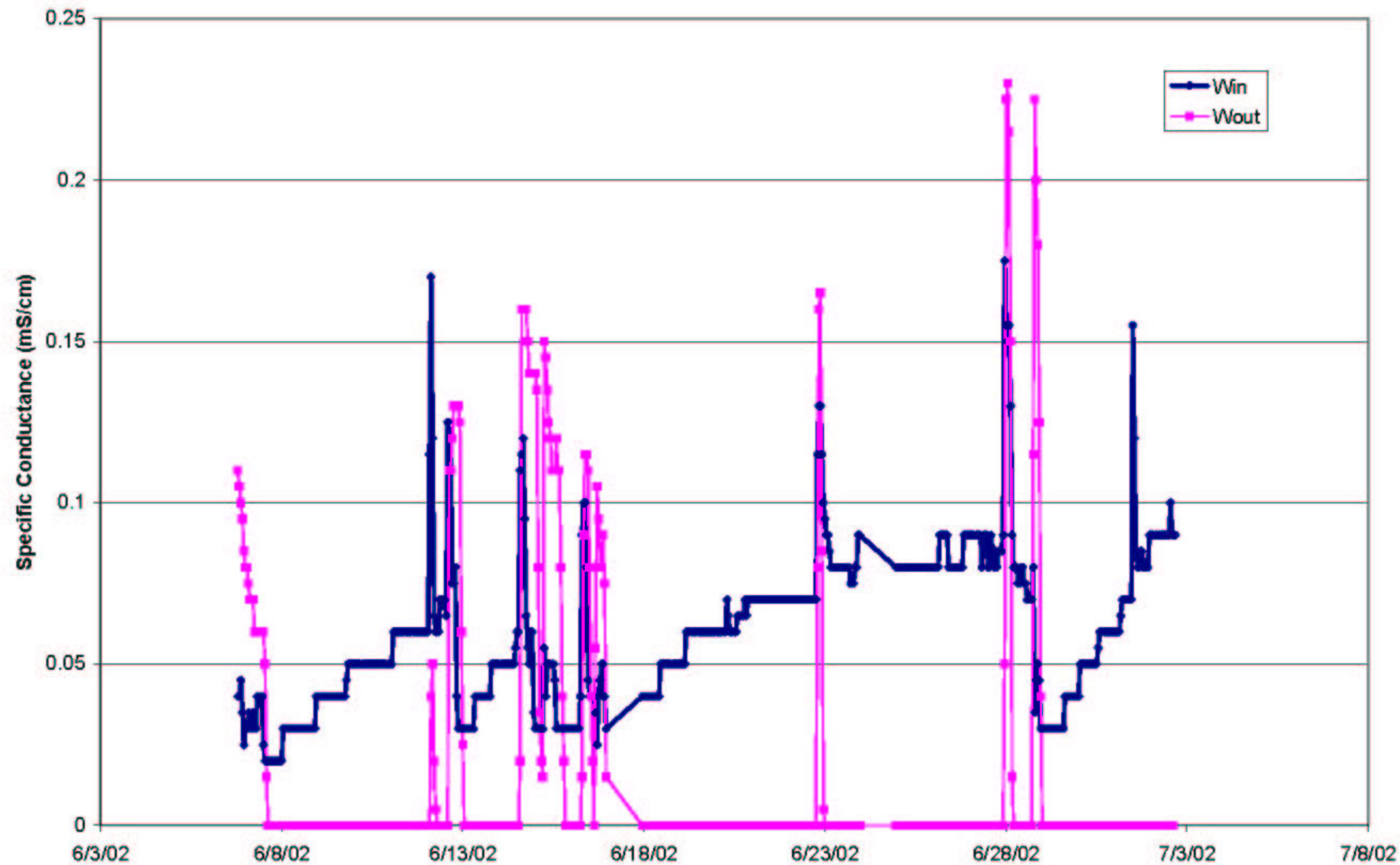
APPENDIX D

Dissolved Oxygen Measurements at the Outfall 001 Oil/Water Separator and Wetland Outflow, Westover Air Force Reserve Base, Chicopee, MA



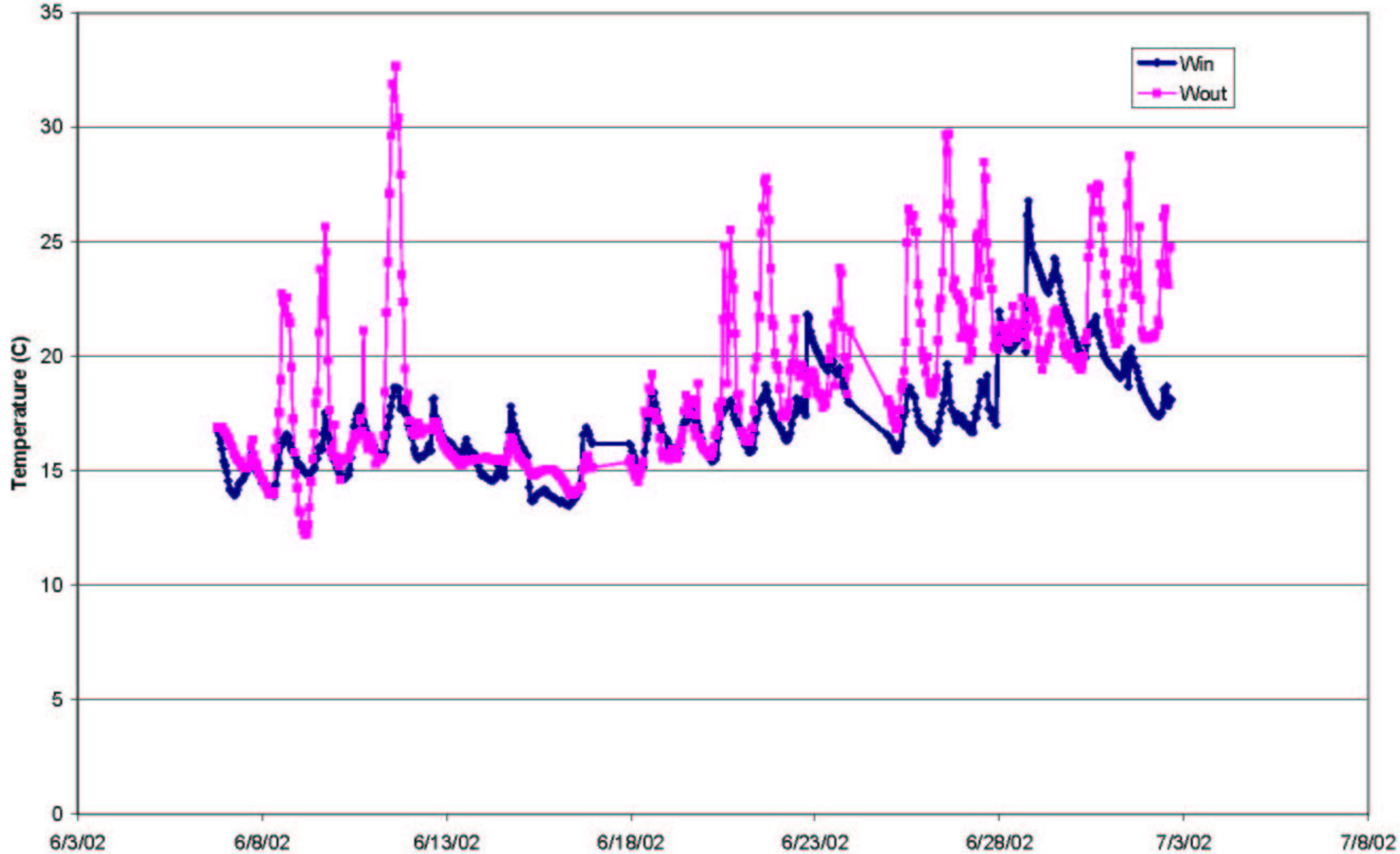
APPENDIX D

pH Measurements at the Outfall 001 Oil/Water Separator and Wetland Outflow, Westover Air Force Reserve Base, Chicopee, MA



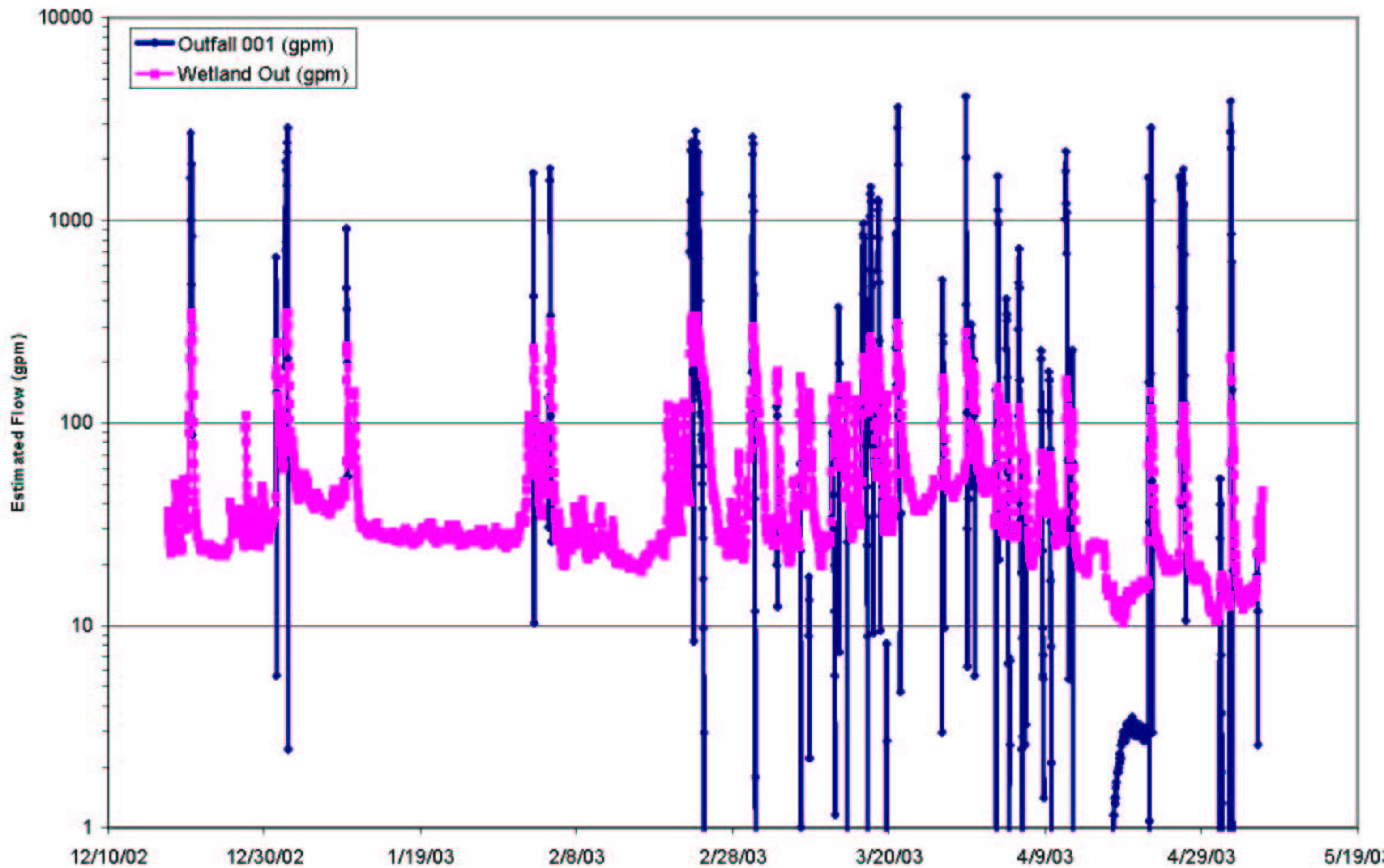
APPENDIX D

Specific Conductance Measurements at the Outfall 001 Oil/Water Separator and Wetland Outflow, Westover Air Force Reserve Base, Chicopee, MA



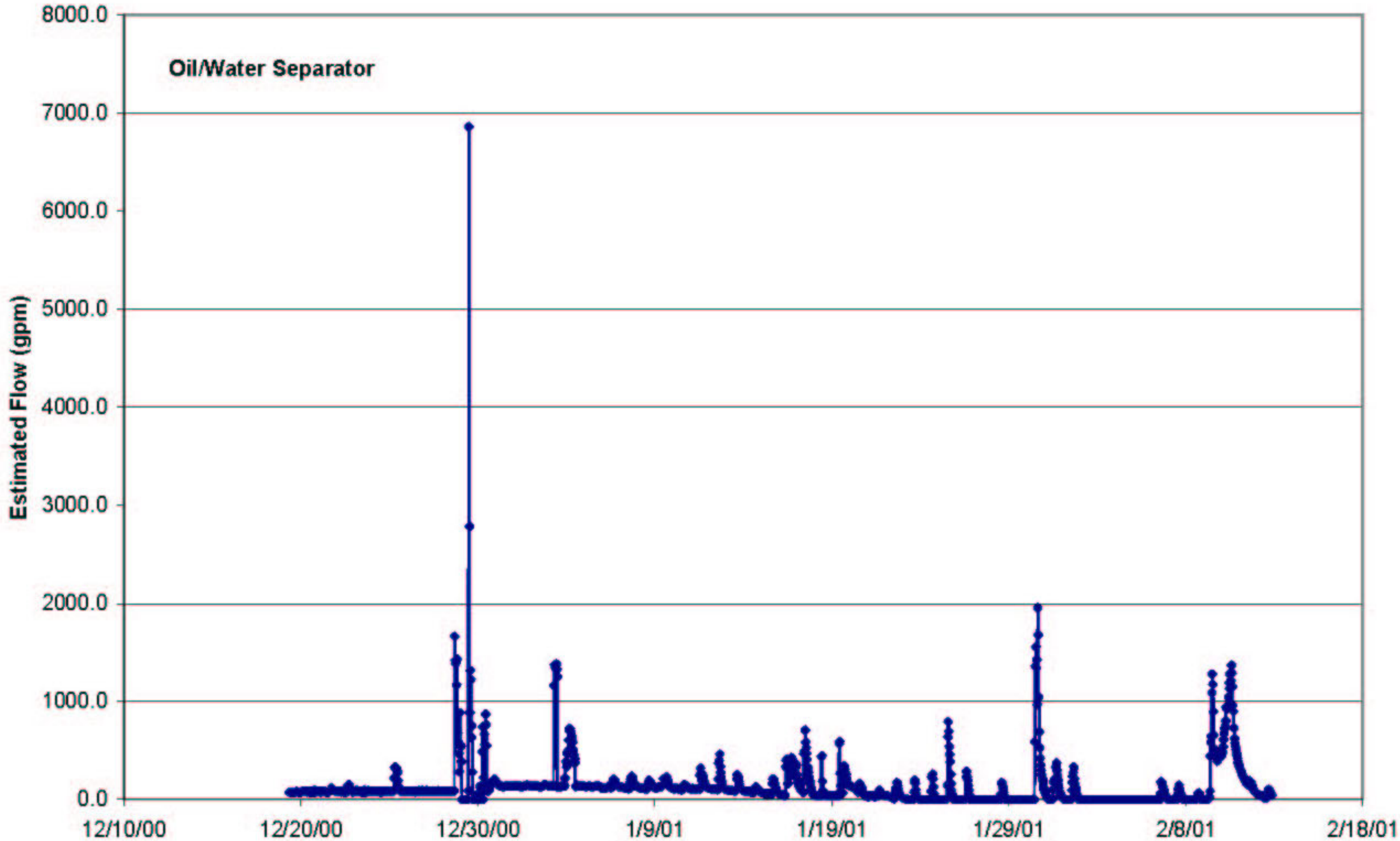
APPENDIX D

Temperature Measurements at the Outfall 001 Oil/Water Separator and Wetland Outflow, Westover Air Force Reserve Base, Chicopee, MA



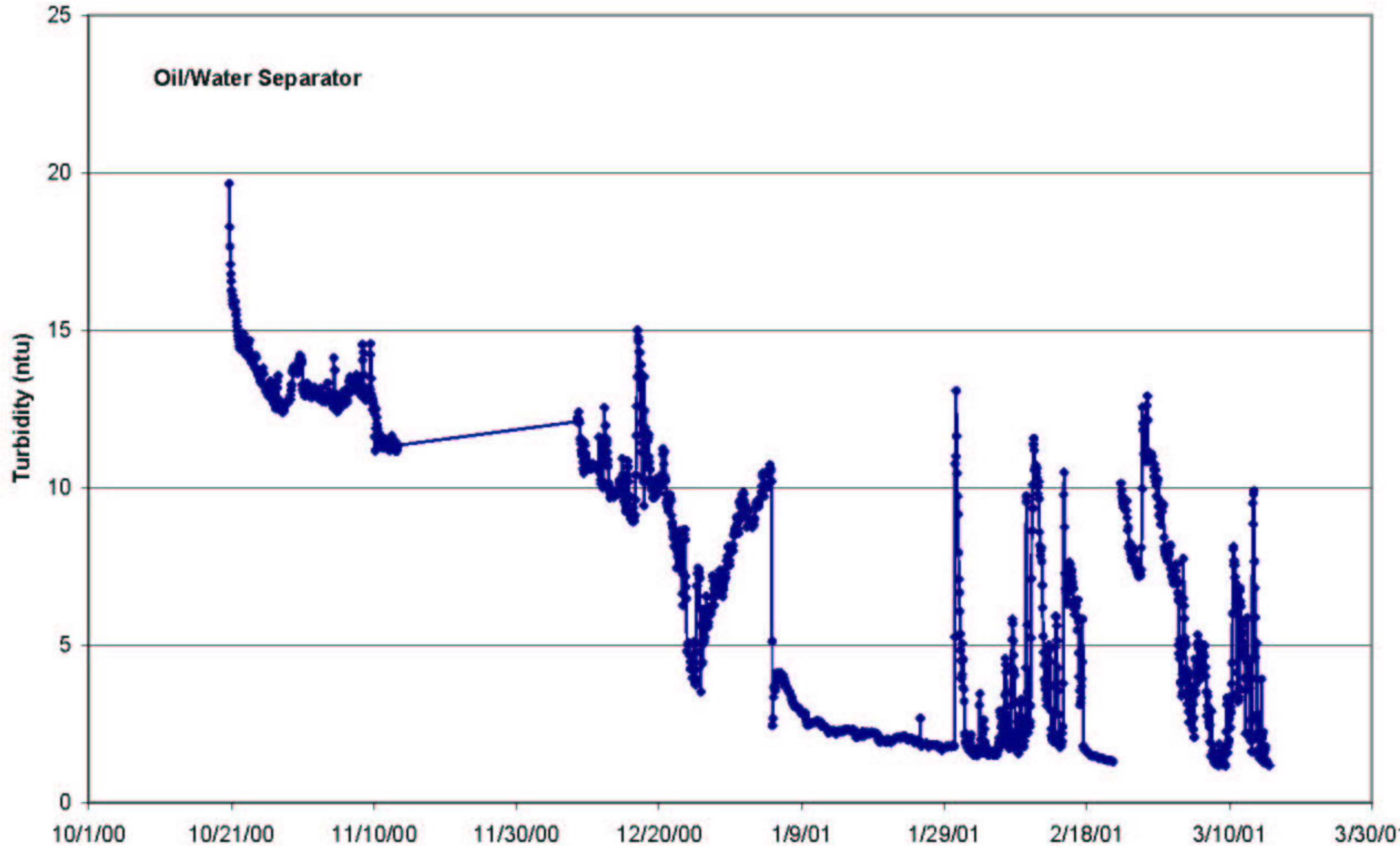
APPENDIX D

Flow Estimates at the Outfall 001 Oil/Water Separator and Wetland Outflow, Westover Air Force Reserve Base, Chicopee, MA



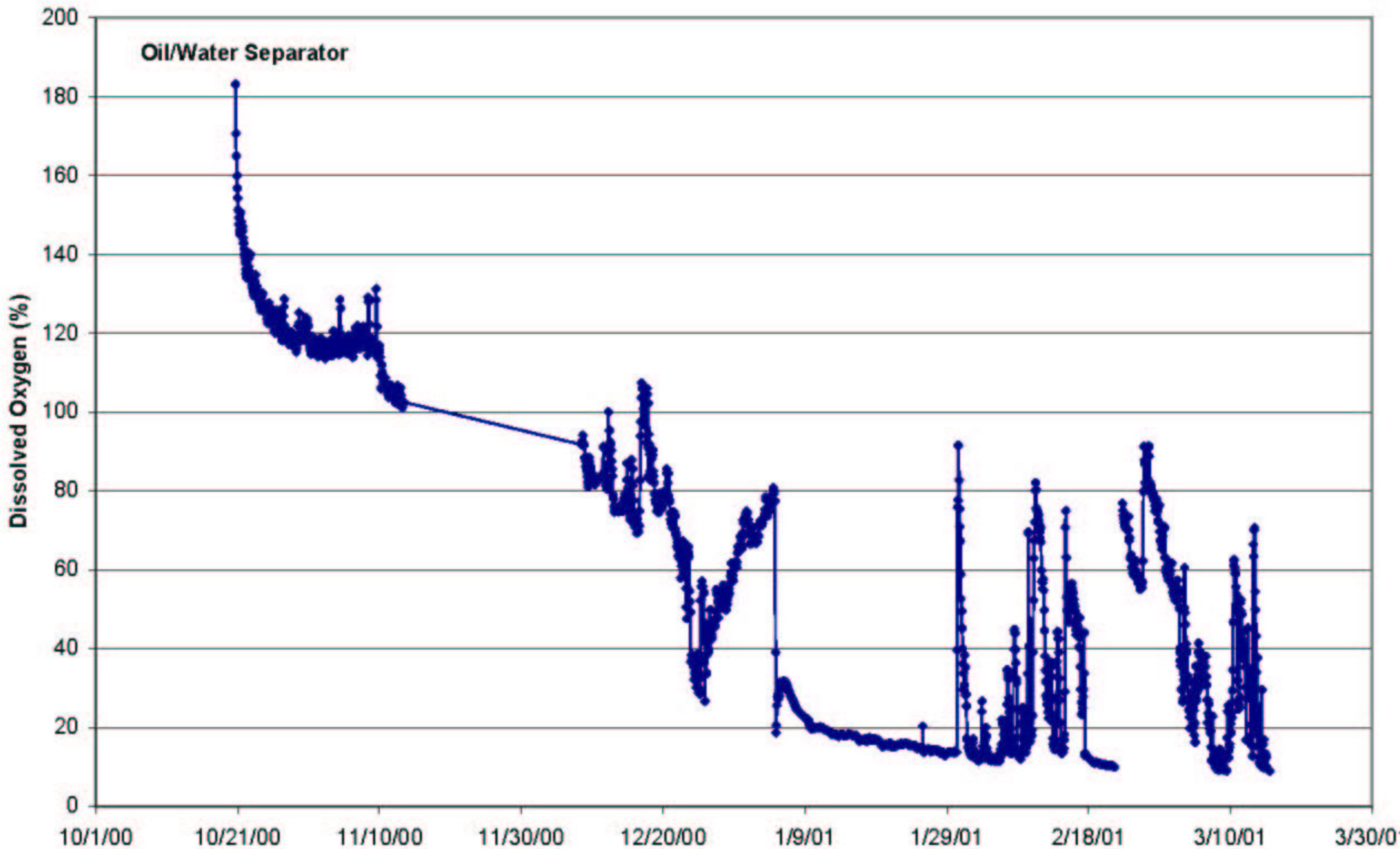
APPENDIX D

Baseline Flows in the Oil/Water Separator to Outfall 001, Westover Air Force Reserve Base, Chicopee, MA



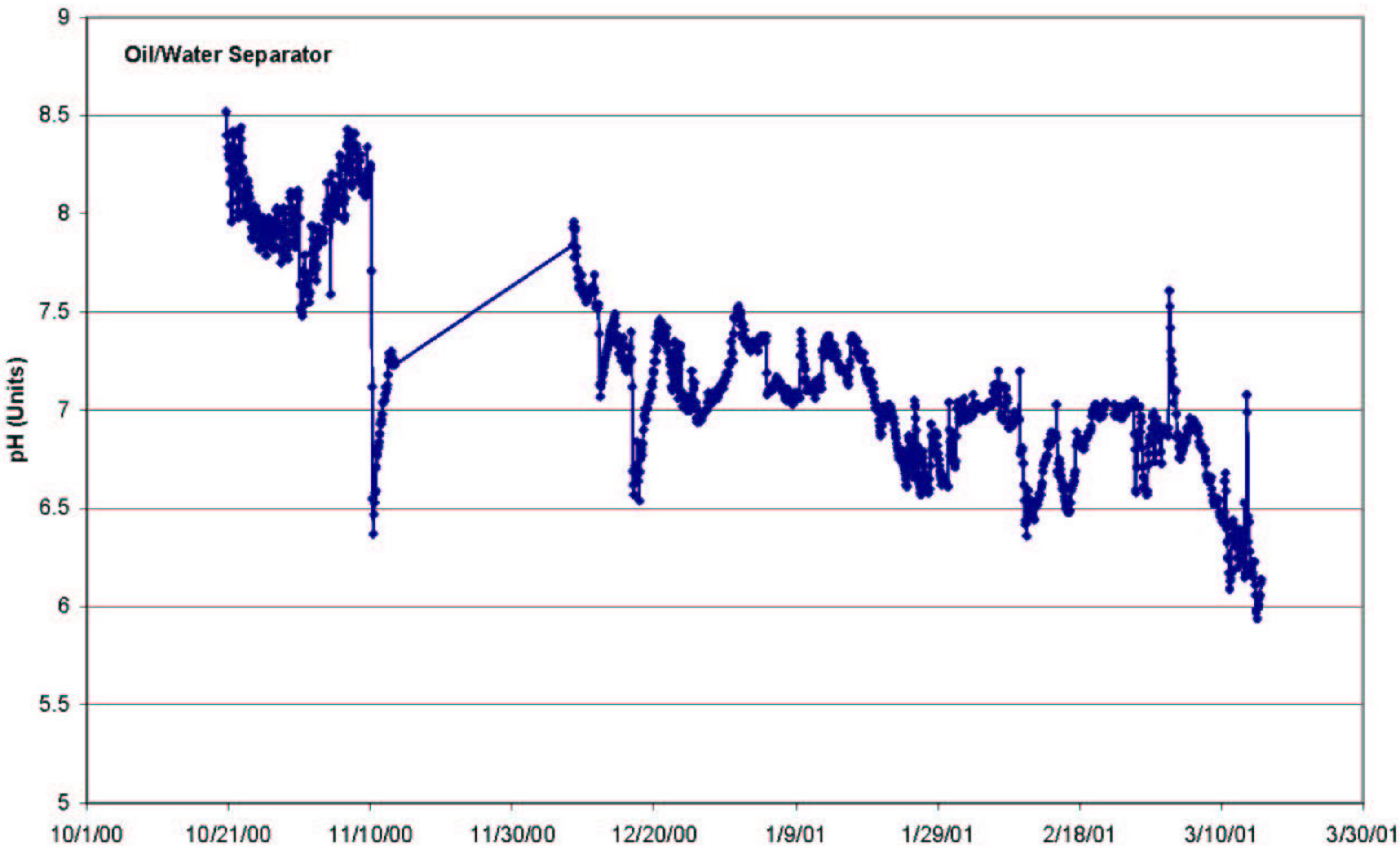
APPENDIX D

Baseline Turbidity Measurements at the Outfall 001 Oil/Water Separator, Westover Air Force Reserve Base, Chicopee, MA



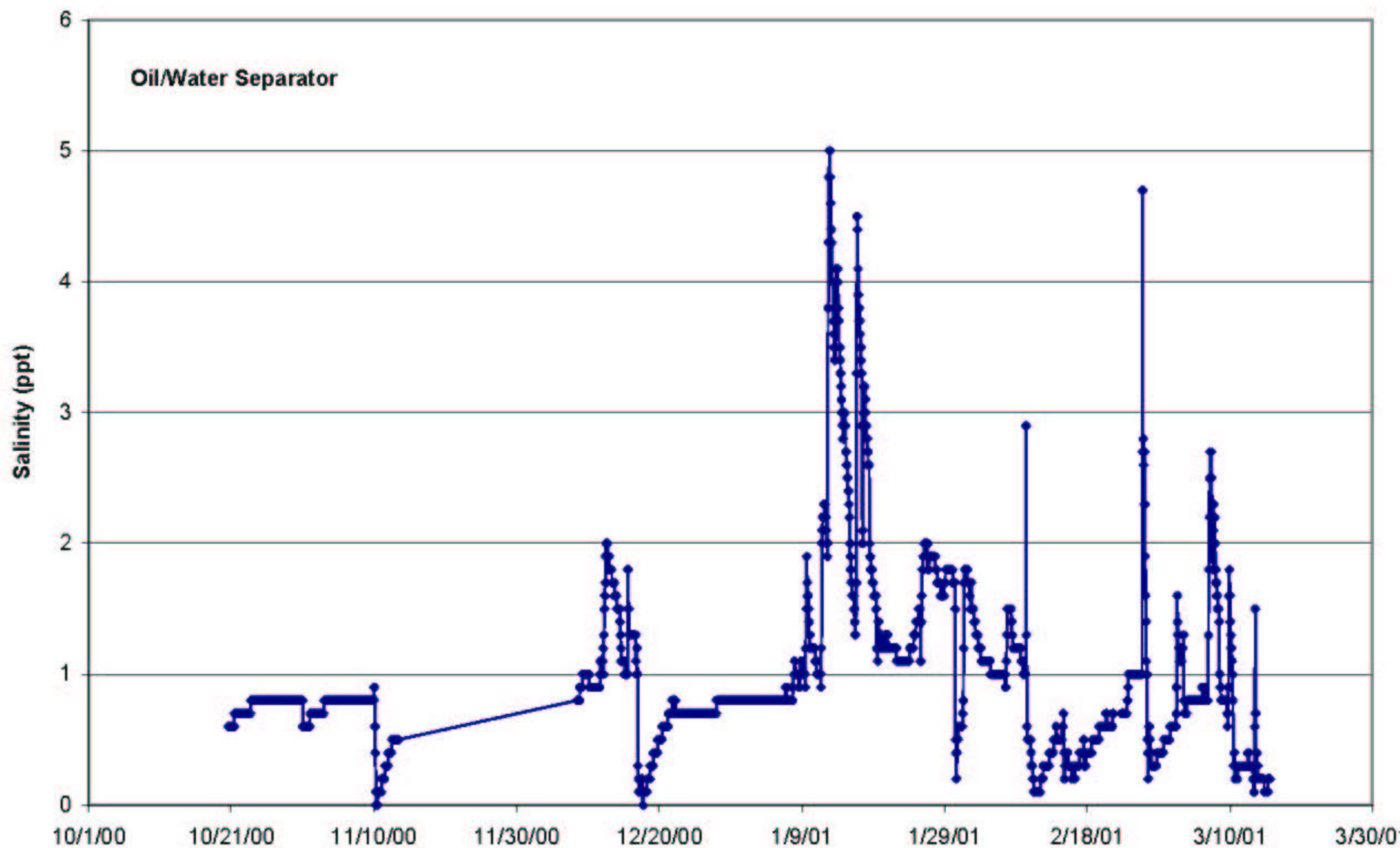
APPENDIX D

Baseline Dissolved Oxygen Measurements at the Outfall 001 Oil/Water Separator, Westover Air Force Reserve Base, Chicopee, MA

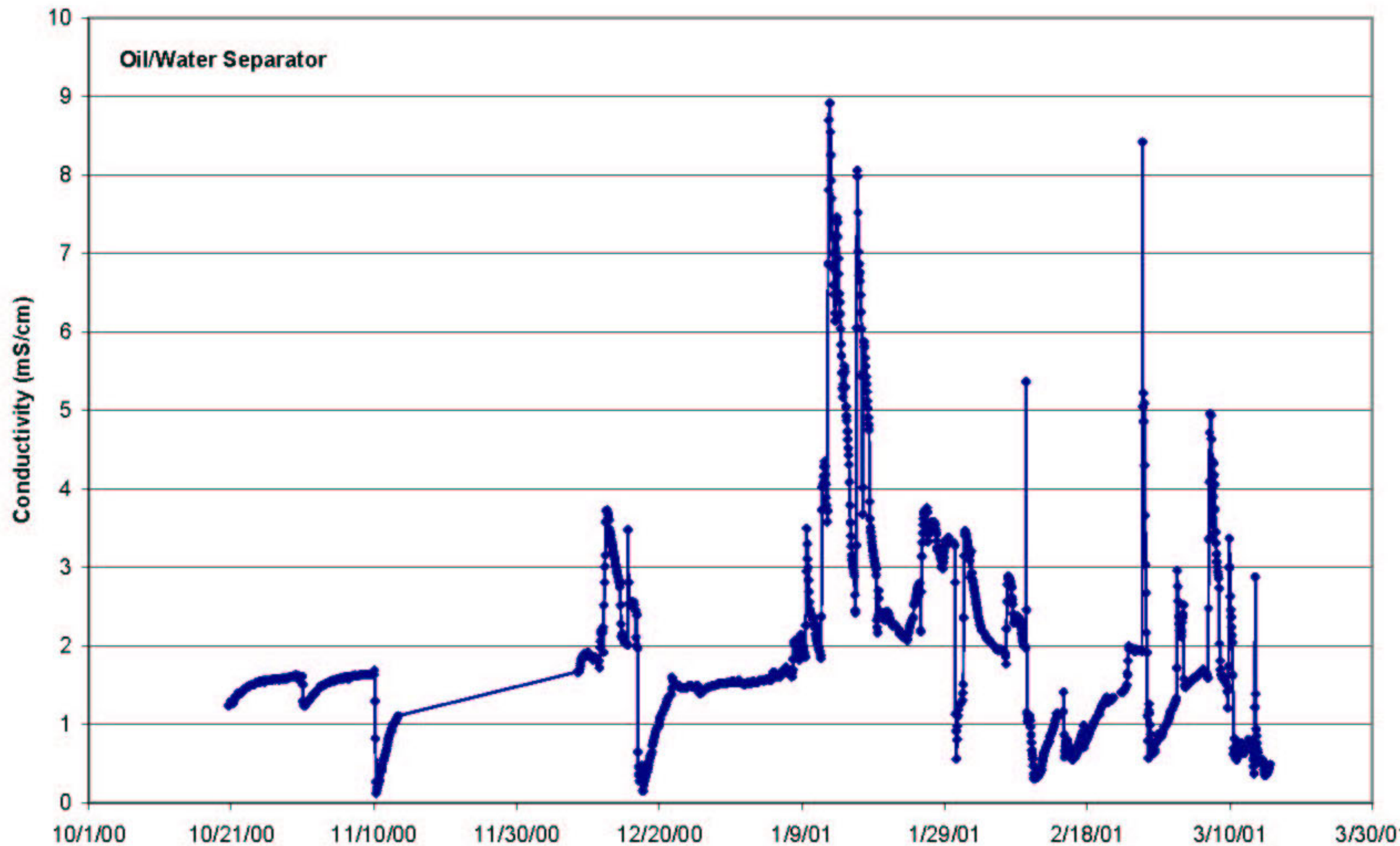


APPENDIX D

Baseline pH Measurements at the Outfall 001 Oil/Water Separator, Westover Air Force Reserve Base, Chicopee, MA

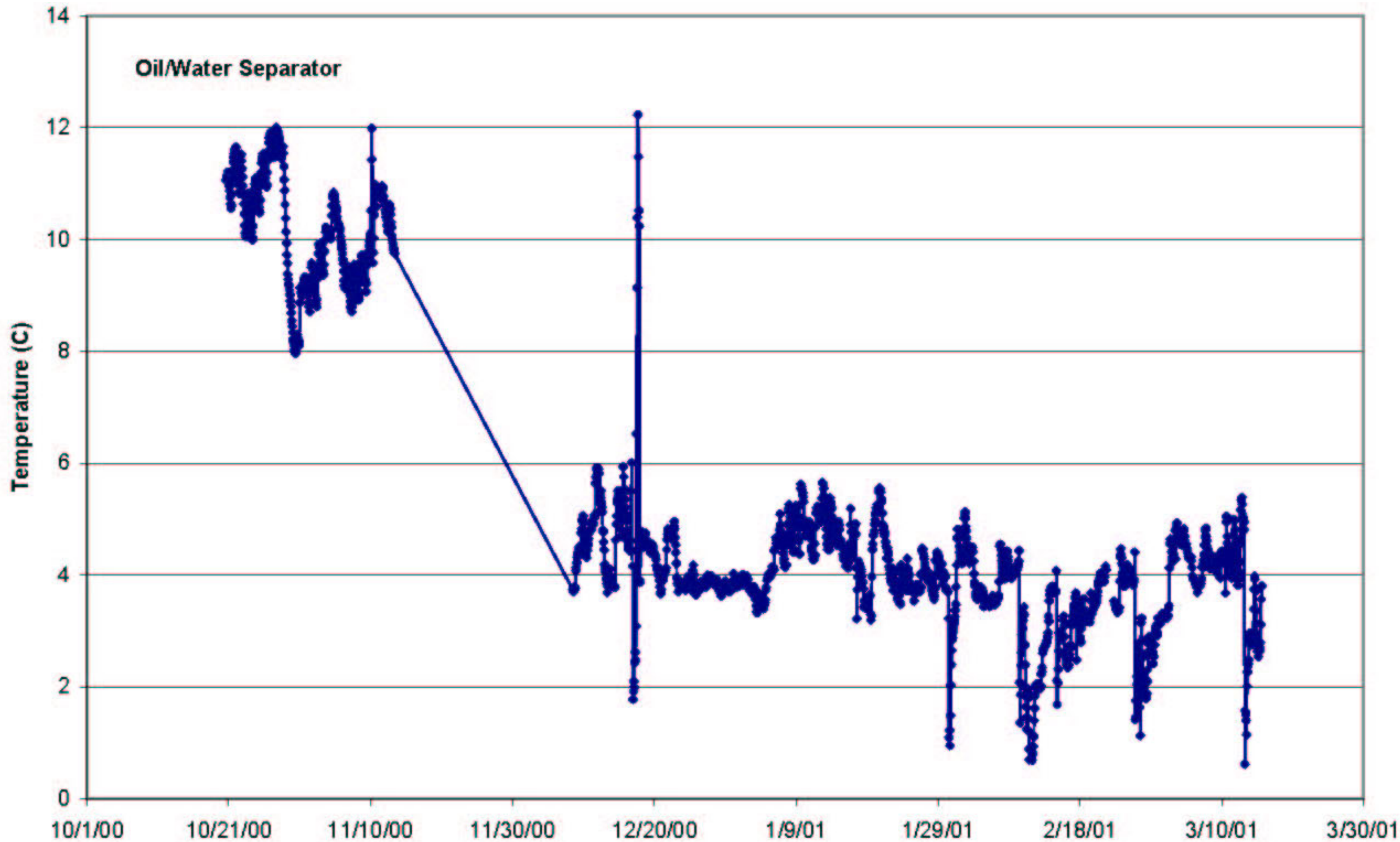


APPENDIX D
Baseline Salinity Measurements at the Outfall 001 Oil/Water Separator, Westover Air Force Reserve Base, Chicopee, MA



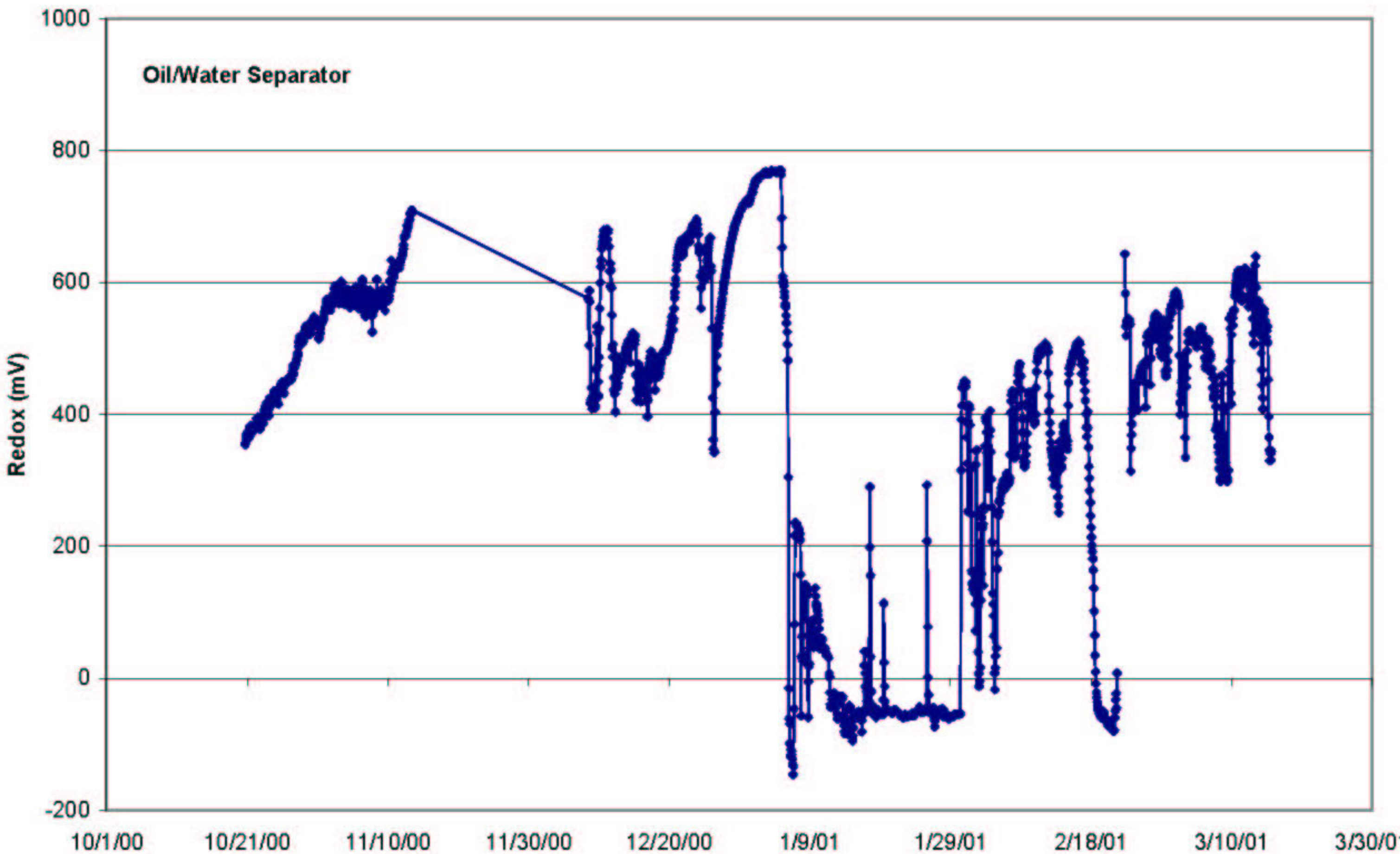
APPENDIX D

Baseline Conductivity Measurements at the Outfall 001 Oil/Water Separator, Westover Air Force Reserve Base, Chicopee, MA



APPENDIX D

Baseline Temperature Measurements at the Outfall 001 Oil/Water Separator, Westover Air Force Reserve Base, Chicopee, MA



APPENDIX D

Baseline Redox Measurements at the Outfall 001 Oil/Water Separator, Westover Air Force Reserve Base, Chicopee, MA

Appendix E
Detail Water Quality Data

APPENDIX E

Detailed Laboratory Results and Analytical Data for the SSF CTW Technology Demonstration Project at the Westover Air Force Reserve Base, Chicopee, MA

		Station				
Parameter (Units)	**Date**	**OWin**	**Outfall001**	**Win**	**Wout**	**CB**
1,1,1,2- Tetrachloroethane (ug/L)	11/6/2000 10:35		0.25			
1,1,1-Trichloroethane (ug/L)	11/6/2000 10:35		0.45			
1,1,2-Trichloroethane (ug/L)	11/6/2000 10:35		0.35			
1,1-Dichloroethane (ug/L)	11/6/2000 10:35		0.35			
1,1-Dichloroethylene (ug/L)	11/6/2000 10:35		0.30			
1,1-Dichloropropene (ug/L)	11/6/2000 10:35		0.70			
1,2,3-Trichlorobenzene (ug/L)	11/6/2000 10:35		0.35			
1,2,3-Trichloroprapane (ug/L)	11/6/2000 10:35		0.65			
1,2,4-Trichlorobenzene (ug/L)	11/6/2000 10:35		0.35			
1,2,4-Trimethylbenzene (ug/L)	11/6/2000 10:35		0.35			
1,2-Dibromo-3-Chloropropane (ug/L)	11/6/2000 10:35		0.80			
1,2-Dibromoethane (ug/L)	11/6/2000 10:35		0.35			
1,2-Dichlorobenzene (ug/L)	11/6/2000 10:35		0.40			
1,2-Dichloroethane (ug/L)	11/6/2000 10:35		0.45			
1,2-Dichloropropane (ug/L)	11/6/2000 10:35		0.30			
1,3,5-Trimethylbenzene (ug/L)	11/6/2000 10:35		0.50			
1,3-Dichlorobenzene (ug/L)	11/6/2000 10:35		0.30			
1,3-Dichloropropane (ug/L)	11/6/2000 10:35		0.25			
1,4-Dichlorobenzene (ug/L)	11/6/2000 10:35		0.40			
2,2-Dichloropropane (ug/L)	11/6/2000 10:35		0.45			
2-Butanone (MEK) (ug/L)	11/6/2000 10:35		6.0			
2-Chloroethylvinylether (ug/L)	11/6/2000 10:35		4.8			
2-Chlorotoluene (ug/L)	11/6/2000 10:35		0.30			
2-Hexanone (ug/L)	11/6/2000 10:35		4.9			
2-Methylnaphthalene (ug/L)	11/6/2000 10:35		2.5			
4-Chlorotoluene (ug/L)	11/6/2000 10:35		0.30			
Acenaphthene (ug/L)	11/6/2000 10:35		2.5			
Acenaphthylene (ug/L)	11/6/2000 10:35		2.5			
Acetone (ug/L)	11/6/2000 10:35		25.0			
Acrolein (ug/L)	11/6/2000 10:35		10.0			
Acrylonitrile (ug/L)	11/6/2000 10:35		3.8			
Ammonia (mg/L)	1/17/2001		0.44			
Ammonia (mg/L)	1/18/2001		0.27			
Ammonia (mg/L)	1/19/2001		0.38			
Anthracene (ug/L)	11/6/2000 10:35		2.5			
Antimony (mg/L)	11/6/2000 10:35		0.010			
Arsenic (mg/L)	11/6/2000 10:35		0.025			
Benzene (ug/L)	11/6/2000 10:35		0.30			
Benzene (µg/L)	11/6/2000 10:35		0.15			
Benzo(a)anthracene (ug/L)	11/6/2000 10:35		2.5			
Benzo(a)pyrene (ug/L)	11/6/2000 10:35		2.5			
Benzo(b)fluoranthene (ug/L)	11/6/2000 10:35		2.5			
Benzo(g,h,i)perylene (ug/L)	11/6/2000 10:35		2.5			
Benzo(k)fluoranthene (ug/L)	11/6/2000 10:35		2.5			
Beryllium (mg/L)	11/6/2000 10:35		0.0005			
BOD (mg/L)	2/1/1994		360			
BOD (mg/L)	3/1/1994		62.0			
BOD (mg/L)	4/1/1994		2.0			
BOD (mg/L)	5/1/1994		1.0			
BOD (mg/L)	1/1/1995		6.0			
BOD (mg/L)	2/1/1995		33.0			
BOD (mg/L)	3/1/1995		2.0			
BOD (mg/L)	4/1/1995		1.5			
BOD (mg/L)	5/1/1995		3.0			
BOD (mg/L)	6/1/1995		3.0			
BOD (mg/L)	7/1/1995		6.0			
BOD (mg/L)	8/1/1995		3.0			
BOD (mg/L)	9/1/1995		3.0			
BOD (mg/L)	10/1/1995		9.4			
BOD (mg/L)	11/1/1995		1.0			
BOD (mg/L)	12/1/1995		190			
BOD (mg/L)	1/1/1996		10.0			
BOD (mg/L)	2/1/1996		31.0			
BOD (mg/L)	3/1/1996		9.0			

APPENDIX E

Detailed Laboratory Results and Analytical Data for the SSF CTW Technology Demonstration Project at the Westover Air Force Reserve Base, Chicopee, MA

		Station				
Parameter (Units)	**Date**	**OWin**	**Outfall001**	**Win**	**Wout**	**CB**
BOD (mg/L)	4/1/1996		13.0			
BOD (mg/L)	5/1/1996		16.0			
BOD (mg/L)	6/1/1996		8.0			
BOD (mg/L)	7/1/1996		25.0			
BOD (mg/L)	8/1/1996		49.0			
BOD (mg/L)	9/1/1996		7.0			
BOD (mg/L)	10/1/1996		8.4			
BOD (mg/L)	11/1/1996		6.7			
BOD (mg/L)	12/1/1996		33.0			
BOD (mg/L)	1/1/1997		100			
BOD (mg/L)	2/1/1997		140			
BOD (mg/L)	3/1/1997		1.0			
BOD (mg/L)	4/1/1997		8.0			
BOD (mg/L)	5/1/1997		1.0			
BOD (mg/L)	6/1/1997		3.7			
BOD (mg/L)	7/1/1997		6.6			
BOD (mg/L)	8/1/1997		1.0			
BOD (mg/L)	9/1/1997		1.0			
BOD (mg/L)	10/1/1997		1.0			
BOD (mg/L)	11/1/1997		1.0			
BOD (mg/L)	12/1/1997		1.0			
BOD (mg/L)	1/1/1998		1.0			
BOD (mg/L)	2/1/1998		1.0			
BOD (mg/L)	3/1/1998		11.0			
BOD (mg/L)	4/1/1998		1.0			
BOD (mg/L)	5/1/1998		1.0			
BOD (mg/L)	6/1/1998		1.0			
BOD (mg/L)	7/1/1998		4.2			
BOD (mg/L)	8/1/1998		6.0			
BOD (mg/L)	9/1/1998		20.0			
BOD (mg/L)	10/1/1998		1.0			
BOD (mg/L)	11/1/1998		1.0			
BOD (mg/L)	12/1/1998		1.0			
BOD (mg/L)	1/1/1999		1.0			
BOD (mg/L)	2/1/1999		1.0			
BOD (mg/L)	3/1/1999		1.0			
BOD (mg/L)	4/1/1999		1.0			
BOD (mg/L)	5/1/1999		1.0			
BOD (mg/L)	6/1/1999		6.3			
BOD (mg/L)	7/1/1999		3.0			
BOD (mg/L)	8/1/1999		1.0			
BOD (mg/L)	9/1/1999		1.0			
BOD (mg/L)	10/1/1999		1.0			
BOD (mg/L)	11/1/1999		1.0			
BOD (mg/L)	12/1/1999		1.0			
BOD (mg/L)	1/27/2000 9:16		4.2			
BOD (mg/L)	2/28/2000 11:05		1.0			
BOD (mg/L)	3/22/2000 9:35		1.0			
BOD (mg/L)	4/27/2000 8:58		1.0			
BOD (mg/L)	5/18/2000 8:45		1.0			
BOD (mg/L)	6/6/2000 10:30		1.0			
BOD (mg/L)	7/25/2000 8:40		1.0			
BOD (mg/L)	8/24/2000 8:25		1.0			
BOD (mg/L)	9/26/2000 9:50		1.0			
BOD (mg/L)	10/31/2000 8:35		1.0			
BOD (mg/L)	11/27/2000 9:02		1.0			
BOD (mg/L)	1/5/2001		90.0			
BOD (mg/L)	1/8/2001		1230			
BOD (mg/L)	1/9/2001		1800			
BOD (mg/L)	1/10/2001		1800			
BOD (mg/L)	3/13/2001 10:30		900			
BOD (mg/L)	3/13/2001 12:30		900			
BOD (mg/L)	3/13/2001 14:30		900			
BOD (mg/L)	3/13/2001 16:30		900			

APPENDIX E

Detailed Laboratory Results and Analytical Data for the SSF CTW Technology Demonstration Project at the Westover Air Force Reserve Base, Chicopee, MA

		Station				
Parameter (Units)	**Date**	**OWin**	**Outfall001**	**Win**	**Wout**	**CB**
BOD (mg/L)	3/13/2001 18:30		900			
BOD (mg/L)	3/13/2001 20:30		900			
BOD (mg/L)	3/13/2001 22:30		900			
BOD (mg/L)	3/14/2001 0:30		900			
BOD (mg/L)	3/14/2001 2:30		900			
BOD (mg/L)	3/14/2001 4:30		900			
BOD (mg/L)	3/14/2001 6:30		900			
BOD (mg/L)	3/14/2001 8:30		900			
BOD (mg/L)	3/14/2001 10:30		700			
BOD (mg/L)	3/14/2001 12:30		144			
BOD (mg/L)	3/14/2001 14:30		97.0			
BOD (mg/L)	3/14/2001 16:30		72.0			
BOD (mg/L)	3/14/2001 18:30		53.0			
BOD (mg/L)	3/14/2001 20:30		47.0			
BOD (mg/L)	3/14/2001 22:30		44.0			
BOD (mg/L)	3/15/2001 0:30		48.0			
BOD (mg/L)	3/15/2001 2:30		57.0			
BOD (mg/L)	3/15/2001 4:30		50.0			
BOD (mg/L)	3/15/2001 6:30		55.0			
BOD (mg/L)	3/15/2001 8:30		69.0			
BOD (mg/L)	2/7/2003 9:45			20.8	90.0	
BOD (mg/L)	2/11/2003 8:15			9000	105	
BOD (mg/L)	2/13/2003 11:50			600	600	
BOD (mg/L)	2/20/2003 7:30			12100	12900	
BOD (mg/L)	2/25/2003 8:00			17.8	50.8	
BOD (mg/L)	2/27/2003 9:00				81.2	
BOD (mg/L)	2/27/2003 9:10			260		
BOD (mg/L)	3/4/2003 10:15			16.2	91.9	
BOD (mg/L)	3/6/2003 10:20			52.2	71.4	
BOD (mg/L)	3/20/2003 9:50			75.0		
BOD (mg/L)	3/20/2003 9:52				348	
BOD (mg/L)	4/7/2003				6600	
BOD (mg/L)	4/7/2003 8:37			118		
Bromobenzene (ug/L)	11/6/2000 10:35		0.25			
Bromochloromethane (ug/L)	11/6/2000 10:35		0.35			
Bromodichloromethane (ug/L)	11/6/2000 10:35		0.20			
Bromoform (ug/L)	11/6/2000 10:35		0.60			
Bromomethane (ug/L)	11/6/2000 10:35		0.60			
C11-C22 Aromatics (ug/L)	11/6/2000 10:35		127			
C19-C36 Aliphatics (ug/L)	11/6/2000 10:35		42.0			
C5-C8 Aliphatics (µg/L)	11/6/2000 10:35		34.5			
C9-C10 Aromatics (µg/L)	11/6/2000 10:35		10.0			
C9-C12 Aliphatics (µg/L)	11/6/2000 10:35		17.0			
C9-C18 Aliphatics (ug/L)	11/6/2000 10:35		72.0			
Cadmium (mg/L)	11/6/2000 10:35		0.0003			
Carbon Disulfide (ug/L)	11/6/2000 10:35		1.5			
Carbon Tetrachloride (ug/L)	11/6/2000 10:35		0.25			
Chlorobenzene (ug/L)	11/6/2000 10:35		0.30			
Chlorodibromomethane (ug/L)	11/6/2000 10:35		0.25			
Chloroethane (ug/L)	11/6/2000 10:35		0.40			
Chloroform (ug/L)	11/6/2000 10:35		0.40			
Chloromethane (ug/L)	11/6/2000 10:35		0.60			
Chromium (mg/L)	11/6/2000 10:35		0.002			
Chrysene (ug/L)	11/6/2000 10:35		5.4			
cis-1 ,4-Dichloro-2-Butene (ug/L)	11/6/2000 10:35		1.2			
cis-1,2-Dichloroethylene (ug/L)	11/6/2000 10:35		0.25			
cis-1,3-Dichloropropene (ug/L)	11/6/2000 10:35		0.25			
COD (mg/L)	2/1/1994		2.5			
COD (mg/L)	3/1/1994		2.5			
COD (mg/L)	4/1/1994		44.0			
COD (mg/L)	5/1/1994		18.0			
COD (mg/L)	1/1/1995		700			
COD (mg/L)	2/1/1995		87.0			
COD (mg/L)	3/1/1995		15.0			

APPENDIX E

Detailed Laboratory Results and Analytical Data for the SSF CTW Technology Demonstration Project at the Westover Air Force Reserve Base, Chicopee, MA

		Station				
Parameter (Units)	**Date**	**OWin**	**Outfall001**	**Win**	**Wout**	**CB**
COD (mg/L)	4/1/1995		16.0			
COD (mg/L)	5/1/1995		14.0			
COD (mg/L)	6/1/1995		32.0			
COD (mg/L)	7/1/1995		20.5			
COD (mg/L)	8/1/1995		18.7			
COD (mg/L)	9/1/1995		12.2			
COD (mg/L)	10/1/1995		16.0			
COD (mg/L)	11/1/1995		10.0			
COD (mg/L)	12/1/1995		2000			
COD (mg/L)	1/1/1996		51.0			
COD (mg/L)	2/1/1996		29.0			
COD (mg/L)	3/1/1996		27.0			
COD (mg/L)	4/1/1996		15.0			
COD (mg/L)	5/1/1996		2.5			
COD (mg/L)	6/1/1996		55.0			
COD (mg/L)	7/1/1996		2.5			
COD (mg/L)	8/1/1996		5.0			
COD (mg/L)	9/1/1996		11.0			
COD (mg/L)	10/1/1996		2.5			
COD (mg/L)	11/1/1996		25.0			
COD (mg/L)	12/1/1996		7.0			
COD (mg/L)	1/1/1997		110			
COD (mg/L)	2/1/1997		220			
COD (mg/L)	3/1/1997		2.5			
COD (mg/L)	4/1/1997		7.0			
COD (mg/L)	5/1/1997		2.5			
COD (mg/L)	6/1/1997		9.0			
COD (mg/L)	7/1/1997		2.5			
COD (mg/L)	8/1/1997		10.0			
COD (mg/L)	9/1/1997		20.0			
COD (mg/L)	10/1/1997		2.5			
COD (mg/L)	11/1/1997		2.5			
COD (mg/L)	12/1/1997		2.5			
COD (mg/L)	1/1/1998		41.0			
COD (mg/L)	2/1/1998		2.5			
COD (mg/L)	3/1/1998		46.0			
COD (mg/L)	4/1/1998		2.5			
COD (mg/L)	5/1/1998		2.5			
COD (mg/L)	6/1/1998		2.5			
COD (mg/L)	7/1/1998		5.0			
COD (mg/L)	8/1/1998		17.0			
COD (mg/L)	9/1/1998		100			
COD (mg/L)	10/1/1998		2.5			
COD (mg/L)	11/1/1998		2.5			
COD (mg/L)	12/1/1998		2.5			
COD (mg/L)	1/1/1999		2.5			
COD (mg/L)	2/1/1999		2.5			
COD (mg/L)	3/1/1999		17.0			
COD (mg/L)	4/1/1999		16.0			
COD (mg/L)	5/1/1999		2.5			
COD (mg/L)	6/1/1999		28.0			
COD (mg/L)	7/1/1999		11.6			
COD (mg/L)	8/1/1999		2.5			
COD (mg/L)	9/1/1999		2.5			
COD (mg/L)	10/1/1999		2.5			
COD (mg/L)	11/1/1999		24.2			
COD (mg/L)	12/1/1999		19.3			
COD (mg/L)	1/27/2000 9:16		20.0			
COD (mg/L)	1/5/2001		549			
COD (mg/L)	1/8/2001		1900			
COD (mg/L)	1/9/2001		13240			
COD (mg/L)	1/17/2001		1640			
COD (mg/L)	1/18/2001		427			
COD (mg/L)	1/19/2001		207			7.5

APPENDIX E

Detailed Laboratory Results and Analytical Data for the SSF CTW Technology Demonstration Project at the Westover Air Force Reserve Base, Chicopee, MA

		Station				
Parameter (Units)	**Date**	**OWin**	**Outfall001**	**Win**	**Wout**	**CB**
COD (mg/L)	1/24/2001		1120			
COD (mg/L)	1/31/2001		52.8			
COD (mg/L)	2/2/2001		38.6			
COD (mg/L)	3/13/2001 10:30		9700			
COD (mg/L)	3/13/2001 12:30		21500			
COD (mg/L)	3/13/2001 14:30		14200			
COD (mg/L)	3/13/2001 16:30		10400			
COD (mg/L)	3/13/2001 18:30		7800			
COD (mg/L)	3/13/2001 20:30		4500			
COD (mg/L)	3/13/2001 22:30		5800			
COD (mg/L)	3/14/2001 0:30		7100			
COD (mg/L)	3/14/2001 2:30		6500			
COD (mg/L)	3/14/2001 4:30		4500			
COD (mg/L)	3/14/2001 6:30		2700			
COD (mg/L)	3/14/2001 8:30		2300			
COD (mg/L)	3/14/2001 10:30		1500			
COD (mg/L)	3/14/2001 12:30		250			
COD (mg/L)	3/14/2001 14:30		196			
COD (mg/L)	3/14/2001 16:30		129			
COD (mg/L)	3/14/2001 18:30		103			
COD (mg/L)	3/14/2001 20:30		95.0			
COD (mg/L)	3/14/2001 22:30		90.0			
COD (mg/L)	3/15/2001 0:30		86.0			
COD (mg/L)	3/15/2001 2:30		83.0			
COD (mg/L)	3/15/2001 4:30		92.0			
COD (mg/L)	3/15/2001 6:30		95.0			
COD (mg/L)	3/15/2001 8:30		115			
COD (mg/L)	3/20/2002 11:40			27.0		
COD (mg/L)	3/20/2002 13:40			13.0		
COD (mg/L)	3/20/2002 15:40			17.0		
COD (mg/L)	3/20/2002 17:40			7.0		
COD (mg/L)	3/20/2002 19:40			10.0		
COD (mg/L)	3/20/2002 21:40			15.0		
COD (mg/L)	3/20/2002 23:40			9.0		
COD (mg/L)	3/21/2002 1:40			11.0		
COD (mg/L)	3/21/2002 3:40			2.5		
COD (mg/L)	3/21/2002 5:40			7400		
COD (mg/L)	3/21/2002 7:40			21500		
COD (mg/L)	3/21/2002 9:40			3200		
COD (mg/L)	3/21/2002 11:40			520		
COD (mg/L)	3/21/2002 13:40			1100		
COD (mg/L)	3/21/2002 15:40			270		
COD (mg/L)	3/21/2002 17:40			130		
COD (mg/L)	3/21/2002 19:40			52.0		
COD (mg/L)	3/21/2002 21:40			120		
COD (mg/L)	3/21/2002 23:40			190		
COD (mg/L)	3/22/2002 1:40			280		
COD (mg/L)	3/22/2002 3:40			290		
COD (mg/L)	3/22/2002 5:40			230		
COD (mg/L)	3/22/2002 7:40			230		
COD (mg/L)	3/22/2002 9:40			230		
COD (mg/L)	3/28/2002 11:30				700	
COD (mg/L)	3/28/2002 15:30				670	
COD (mg/L)	3/28/2002 19:30				700	
COD (mg/L)	3/28/2002 23:30				720	
COD (mg/L)	3/29/2002 7:30				590	
COD (mg/L)	3/29/2002 11:30				930	
COD (mg/L)	3/29/2002 15:30				1400	
COD (mg/L)	3/29/2002 19:30				1800	
COD (mg/L)	3/29/2002 23:30				1900	
COD (mg/L)	3/30/2002 3:30				1900	
COD (mg/L)	3/30/2002 7:30				630	
COD (mg/L)	3/30/2002 11:30				530	
COD (mg/L)	3/30/2002 15:30				680	

APPENDIX E

Detailed Laboratory Results and Analytical Data for the SSF CTW Technology Demonstration Project at the Westover Air Force Reserve Base, Chicopee, MA

		Station				
Parameter (Units)	**Date**	**OWin**	**Outfall001**	**Win**	**Wout**	**CB**
COD (mg/L)	3/30/2002 19:30				930	
COD (mg/L)	3/30/2002 23:30				1200	
COD (mg/L)	3/31/2002 3:30				1100	
COD (mg/L)	3/31/2002 7:30				1100	
COD (mg/L)	3/31/2002 11:30				1000	
COD (mg/L)	3/31/2002 15:30				1400	
COD (mg/L)	3/31/2002 19:30				1500	
COD (mg/L)	3/31/2002 23:30				1500	
COD (mg/L)	4/1/2002 3:30				480	
COD (mg/L)	4/1/2002 7:30				100	
COD (mg/L)	4/4/2002 10:19			2.5		
COD (mg/L)	4/4/2002 10:49			2.5		
COD (mg/L)	4/4/2002 11:22			2.5		
COD (mg/L)	4/4/2002 13:20			2.5		
COD (mg/L)	4/4/2002 13:34			2.5		
COD (mg/L)	4/4/2002 14:34			25.0		
COD (mg/L)	4/4/2002 15:34			10.0		
COD (mg/L)	4/4/2002 16:34			230		
COD (mg/L)	4/4/2002 17:34			700		
COD (mg/L)	4/4/2002 19:34			1080		
COD (mg/L)	4/4/2002 21:34			1270		
COD (mg/L)	4/5/2002 1:34			1050		
COD (mg/L)	4/5/2002 3:34			920		
COD (mg/L)	4/5/2002 5:34			870		
COD (mg/L)	4/5/2002 7:34			850		
COD (mg/L)	4/5/2002 9:34			680		
COD (mg/L)	4/5/2002 11:50			83.0		
COD (mg/L)	4/5/2002 12:00			460		
COD (mg/L)	4/5/2002 14:00			510		
COD (mg/L)	4/5/2002 16:00			530		
COD (mg/L)	4/5/2002 18:00			550	300	
COD (mg/L)	4/5/2002 20:00			450	320	
COD (mg/L)	4/5/2002 22:00			350		
COD (mg/L)	4/5/2002 23:34			1200		
COD (mg/L)	4/6/2002			300		
COD (mg/L)	4/6/2002 2:00			230	330	
COD (mg/L)	4/6/2002 4:00			190		
COD (mg/L)	4/6/2002 6:00			170	310	
COD (mg/L)	4/6/2002 8:00			200		
COD (mg/L)	4/6/2002 10:00			92.0	340	
COD (mg/L)	4/6/2002 12:00			57.0		
COD (mg/L)	4/6/2002 14:00			57.0	360	
COD (mg/L)	4/6/2002 16:00			110		
COD (mg/L)	4/6/2002 18:00			120	380	
COD (mg/L)	4/6/2002 20:00			110		
COD (mg/L)	4/6/2002 22:00			100	370	
COD (mg/L)	4/7/2002			94.0		
COD (mg/L)	4/7/2002 2:00			83.0	370	
COD (mg/L)	4/7/2002 4:00			81.0		
COD (mg/L)	4/7/2002 6:00			62.0	350	
COD (mg/L)	4/7/2002 8:00			25.0		
COD (mg/L)	4/7/2002 10:00				620	
COD (mg/L)	4/7/2002 14:00				410	
COD (mg/L)	4/7/2002 18:00				410	
COD (mg/L)	4/7/2002 22:00				260	
COD (mg/L)	4/8/2002 2:00				190	
COD (mg/L)	4/8/2002 6:00				150	
COD (mg/L)	4/8/2002 10:00				150	
COD (mg/L)	4/8/2002 14:00				210	
COD (mg/L)	4/8/2002 18:00				190	
COD (mg/L)	4/8/2002 22:00				210	
COD (mg/L)	4/9/2002 2:00				310	
COD (mg/L)	4/9/2002 6:00				250	
COD (mg/L)	4/9/2002 10:00				220	

APPENDIX E

Detailed Laboratory Results and Analytical Data for the SSF CTW Technology Demonstration Project at the Westover Air Force Reserve Base, Chicopee, MA

		Station				
Parameter (Units)	**Date**	**OWin**	**Outfall001**	**Win**	**Wout**	**CB**
COD (mg/L)	4/9/2002 14:00				310	
COD (mg/L)	2/7/2003 9:45			43.0	168	
COD (mg/L)	2/11/2003 8:15			31800	180	
COD (mg/L)	2/13/2003 11:50			37900	8700	
COD (mg/L)	2/20/2003 7:30			22800	23100	
COD (mg/L)	2/25/2003 8:00			44.8	107	
COD (mg/L)	2/27/2003 9:00				148	
COD (mg/L)	2/27/2003 9:10			453		
COD (mg/L)	3/4/2003 10:15			41.0	171	
COD (mg/L)	3/6/2003 10:20			100	109	
COD (mg/L)	3/20/2003 9:50			96.0		
COD (mg/L)	3/20/2003 9:52				628	
COD (mg/L)	4/7/2003				12000	
COD (mg/L)	4/7/2003 8:37			53.8		
Copper (mg/L)	11/6/2000 10:35		0.0005			
Dibenzo (a,h (anthracene (ug/L)	11/6/2000 10:35		2.5			
Dibromomethane (ug/L)	11/6/2000 10:35		0.55			
Dichlorodifluoromethane (ug/L)	11/6/2000 10:35		0.50			
Ethyl Benzene (ug/L)	11/6/2000 10:35		0.30			
Ethyl Benzene (µg/L)	11/6/2000 10:35		0.20			
Ethyl Methacrylate (ug/L)	11/6/2000 10:35		0.40			
Fluoranthene (ug/L)	11/6/2000 10:35		2.5			
Fluorene (ug/L)	11/6/2000 10:35		2.5			
Hexachlorobutadiene (ug/L)	11/6/2000 10:35		0.65			
Indeno (1,2,3-cd)pyrene (ug/L)	11/6/2000 10:35		2.5			
Isopropylbenzene (ug/L)	11/6/2000 10:35		0.30			
I' 1,2,2- Tetrachloroethane (ug/L)	11/6/2000 10:35		0.70			
Lead (mg/L)	11/6/2000 10:35		0.010			
Iodomethane (ug/L)	11/6/2000 10:35		0.40			
m/p-Xylene (µg/L)	11/6/2000 10:35		1.4			
m+p Xylene (ug/L)	11/6/2000 10:35		0.65			
MeBT (mg/L)	3/20/2002 11:40			0.024		
MeBT (mg/L)	3/20/2002 13:40			0.024		
MeBT (mg/L)	3/20/2002 15:40			0.024		
MeBT (mg/L)	3/20/2002 17:40			0.024		
MeBT (mg/L)	3/20/2002 19:40			0.024		
MeBT (mg/L)	3/20/2002 21:40			0.024		
MeBT (mg/L)	3/20/2002 23:40			0.024		
MeBT (mg/L)	3/21/2002 1:40			0.065		
MeBT (mg/L)	3/21/2002 3:40			0.024		
MeBT (mg/L)	3/21/2002 5:40			6.6		
MeBT (mg/L)	3/21/2002 7:40			20.9		
MeBT (mg/L)	3/21/2002 9:40			1.5		
MeBT (mg/L)	3/21/2002 11:40			0.30		
MeBT (mg/L)	3/21/2002 13:40			0.54		
MeBT (mg/L)	3/21/2002 15:40			0.15		
MeBT (mg/L)	3/21/2002 17:40			0.085		
MeBT (mg/L)	3/21/2002 19:40			0.049		
MeBT (mg/L)	3/21/2002 21:40			0.31		
MeBT (mg/L)	3/21/2002 23:40			2.7		
MeBT (mg/L)	3/22/2002 1:40			0.14		
MeBT (mg/L)	3/22/2002 3:40			0.16		
MeBT (mg/L)	3/22/2002 5:40			0.98		
MeBT (mg/L)	3/22/2002 7:40			0.16		
MeBT (mg/L)	3/22/2002 9:40			0.16		
MeBT (mg/L)	3/28/2002 11:30				0.47	
MeBT (mg/L)	3/28/2002 15:30				0.48	
MeBT (mg/L)	3/28/2002 19:30				0.46	
MeBT (mg/L)	3/28/2002 23:30				0.53	
MeBT (mg/L)	3/29/2002 7:30				0.47	
MeBT (mg/L)	3/29/2002 11:30				1.1	
MeBT (mg/L)	3/29/2002 15:30				0.70	
MeBT (mg/L)	3/29/2002 19:30				0.88	
MeBT (mg/L)	3/29/2002 23:30				0.89	

APPENDIX E

Detailed Laboratory Results and Analytical Data for the SSF CTW Technology Demonstration Project at the Westover Air Force Reserve Base, Chicopee, MA

		Station				
Parameter (Units)	**Date**	**OWin**	**Outfall001**	**Win**	**Wout**	**CB**
MeBT (mg/L)	3/30/2002 3:30				0.93	
MeBT (mg/L)	3/30/2002 7:30				0.88	
MeBT (mg/L)	3/30/2002 11:30				1.6	
MeBT (mg/L)	3/30/2002 15:30				0.75	
MeBT (mg/L)	3/30/2002 19:30				0.88	
MeBT (mg/L)	3/30/2002 23:30				1.5	
MeBT (mg/L)	3/31/2002 3:30				1.4	
MeBT (mg/L)	3/31/2002 7:30				1.5	
MeBT (mg/L)	3/31/2002 11:30				4.8	
MeBT (mg/L)	3/31/2002 15:30				1.7	
MeBT (mg/L)	3/31/2002 19:30				1.9	
MeBT (mg/L)	3/31/2002 23:30				2.0	
MeBT (mg/L)	4/1/2002 3:30				0.39	
MeBT (mg/L)	4/1/2002 7:30				0.11	
MeBT (mg/L)	4/4/2002 10:19				0.024	
MeBT (mg/L)	4/4/2002 10:49				0.024	
MeBT (mg/L)	4/4/2002 11:22				0.024	
MeBT (mg/L)	4/4/2002 13:20				0.024	
MeBT (mg/L)	4/4/2002 13:34			0.024	0.024	
MeBT (mg/L)	4/4/2002 14:34			0.069		
MeBT (mg/L)	4/4/2002 15:34			0.12		
MeBT (mg/L)	4/4/2002 16:34			0.91		
MeBT (mg/L)	4/4/2002 17:34			1.1		
MeBT (mg/L)	4/4/2002 19:34			1.4		
MeBT (mg/L)	4/4/2002 21:34			1.6		
MeBT (mg/L)	4/5/2002 1:34			1.3		
MeBT (mg/L)	4/5/2002 3:34			1.2		
MeBT (mg/L)	4/5/2002 5:34			1.1		
MeBT (mg/L)	4/5/2002 7:34			1.1		
MeBT (mg/L)	4/5/2002 9:34			0.86		
MeBT (mg/L)	4/5/2002 11:50				0.16	
MeBT (mg/L)	4/5/2002 12:00			0.35		
MeBT (mg/L)	4/5/2002 14:00			0.34		
MeBT (mg/L)	4/5/2002 16:00			0.35		
MeBT (mg/L)	4/5/2002 18:00			0.34	0.71	
MeBT (mg/L)	4/5/2002 20:00			0.35	0.51	
MeBT (mg/L)	4/5/2002 22:00			0.26		
MeBT (mg/L)	4/5/2002 23:34			1.5		
MeBT (mg/L)	4/6/2002			0.23		
MeBT (mg/L)	4/6/2002 2:00			0.21	0.51	
MeBT (mg/L)	4/6/2002 4:00			0.19		
MeBT (mg/L)	4/6/2002 6:00			0.18	0.44	
MeBT (mg/L)	4/6/2002 8:00			0.19		
MeBT (mg/L)	4/6/2002 10:00			0.15	0.42	
MeBT (mg/L)	4/6/2002 12:00			0.11		
MeBT (mg/L)	4/6/2002 14:00			0.13	0.43	
MeBT (mg/L)	4/6/2002 16:00			0.14		
MeBT (mg/L)	4/6/2002 18:00			0.16	0.43	
MeBT (mg/L)	4/6/2002 20:00			0.16		
MeBT (mg/L)	4/6/2002 22:00			0.15	0.41	
MeBT (mg/L)	4/7/2002			0.86		
MeBT (mg/L)	4/7/2002			0.14		
MeBT (mg/L)	4/7/2002 2:00			0.12	0.37	
MeBT (mg/L)	4/7/2002 4:00			0.14		
MeBT (mg/L)	4/7/2002 6:00			0.13	0.38	
MeBT (mg/L)	4/7/2002 8:00			0.13		
MeBT (mg/L)	4/7/2002 10:00				0.39	
MeBT (mg/L)	4/7/2002 14:00				0.45	
MeBT (mg/L)	4/7/2002 18:00				0.56	
MeBT (mg/L)	4/7/2002 22:00				0.49	
MeBT (mg/L)	4/8/2002 2:00				0.41	
MeBT (mg/L)	4/8/2002 6:00				0.36	
MeBT (mg/L)	4/8/2002 10:00				0.36	
MeBT (mg/L)	4/8/2002 14:00				0.41	

APPENDIX E

Detailed Laboratory Results and Analytical Data for the SSF CTW Technology Demonstration Project at the Westover Air Force Reserve Base, Chicopee, MA

		Station				
Parameter (Units)	**Date**	**OWin**	**Outfall001**	**Win**	**Wout**	**CB**
MeBT (mg/L)	4/8/2002 18:00				0.42	
MeBT (mg/L)	4/8/2002 22:00				1.7	
MeBT (mg/L)	4/9/2002 2:00				0.40	
MeBT (mg/L)	4/9/2002 6:00				0.39	
MeBT (mg/L)	4/9/2002 10:00				0.40	
MeBT (mg/L)	4/9/2002 14:00				0.43	
Mercury (mg/L)	11/6/2000 10:35		0.0000			
Methylene Chloride (ug/L)	11/6/2000 10:35		1.5			
MIBK (ug/L)	11/6/2000 10:35		4.4			
MTBE (ug/L)	11/6/2000 10:35		0.40			
MTBE (µg/L)	11/6/2000 10:35		1.1			
Naphthalene (ug/L)	11/6/2000 10:35		1.5			
Naphthalene (µg/L)	11/6/2000 10:35		1.6			
n-Butylbenzene (ug/L)	11/6/2000 10:35		0.35			
Nickel (mg/L)	11/6/2000 10:35		0.001			
Nitrate (mg/L)	1/17/2001		1.7			
Nitrate (mg/L)	1/18/2001		1.5			
Nitrate (mg/L)	1/19/2001		1.4			
Nitrite (mg/L)	1/17/2001		0.12			
Nitrite (mg/L)	1/18/2001		0.090			
Nitrite (mg/L)	1/19/2001		0.025			
n-Propylbenzene (ug/L)	11/6/2000 10:35		0.40			
Oil/Grease (mg/L)	1/27/2000 9:16		2.5			
o-Xylene (ug/L)	11/6/2000 10:35		0.25			
o-Xylene (µg/L)	11/6/2000 10:35		0.50			
pH (units)	1/27/2000 9:16		7.9			
pH (units)	2/28/2000 11:05		8.3			
pH (units)	3/22/2000 9:35		8.1			
pH (units)	4/27/2000 8:58		7.8			
pH (units)	5/18/2000 8:45		7.5			
pH (units)	6/6/2000 10:30		7.9			
pH (units)	7/25/2000 8:40		8.2			
pH (units)	8/24/2000 8:25		7.6			
pH (units)	9/26/2000 9:50		8.2			
pH (units)	10/31/2000 8:35		8.2			
pH (units)	11/27/2000 9:02		8.0			
pH (units)	2/27/2003			7.2	7.8	
pH (units)	3/20/2003			7.3	7.5	
Phenanthrene (ug/L)	11/6/2000 10:35		2.5			
p-Isopropyltoluene (ug/L)	11/6/2000 10:35		0.35			
PropyleneGlycol (mg/L)	1/5/2001		300			
PropyleneGlycol (mg/L)	1/8/2001		1000			
PropyleneGlycol (mg/L)	1/9/2001		7550			
PropyleneGlycol (mg/L)	1/17/2001		750			
PropyleneGlycol (mg/L)	1/18/2001		167			
PropyleneGlycol (mg/L)	1/19/2001		76.0			
PropyleneGlycol (mg/L)	1/24/2001	250	603			
PropyleneGlycol (mg/L)	1/31/2001		250			
PropyleneGlycol (mg/L)	2/2/2001		250			
PropyleneGlycol (mg/L)	3/13/2001 10:30		4800			
PropyleneGlycol (mg/L)	3/13/2001 12:30		11000			
PropyleneGlycol (mg/L)	3/13/2001 14:30		6900			
PropyleneGlycol (mg/L)	3/13/2001 16:30		4900			
PropyleneGlycol (mg/L)	3/13/2001 18:30		5200			
PropyleneGlycol (mg/L)	3/13/2001 20:30		2400			
PropyleneGlycol (mg/L)	3/13/2001 22:30		3300			
PropyleneGlycol (mg/L)	3/14/2001 0:30		3800			
PropyleneGlycol (mg/L)	3/14/2001 2:30		3600			
PropyleneGlycol (mg/L)	3/14/2001 4:30		1900			
PropyleneGlycol (mg/L)	3/14/2001 6:30		1600			
PropyleneGlycol (mg/L)	3/14/2001 8:30		950			
PropyleneGlycol (mg/L)	3/14/2001 10:30		810			
PropyleneGlycol (mg/L)	3/14/2001 12:30		66.0			
PropyleneGlycol (mg/L)	3/14/2001 14:30		25.0			

APPENDIX E

Detailed Laboratory Results and Analytical Data for the SSF CTW Technology Demonstration Project at the Westover Air Force Reserve Base, Chicopee, MA

		Station				
Parameter (Units)	**Date**	**OWin**	**Outfall001**	**Win**	**Wout**	**CB**
PropyleneGlycol (mg/L)	3/14/2001 16:30		25.0			
PropyleneGlycol (mg/L)	3/14/2001 18:30		25.0			
PropyleneGlycol (mg/L)	3/14/2001 20:30		25.0			
PropyleneGlycol (mg/L)	3/14/2001 22:30		25.0			
PropyleneGlycol (mg/L)	3/15/2001 0:30		25.0			
PropyleneGlycol (mg/L)	3/15/2001 2:30		25.0			
PropyleneGlycol (mg/L)	3/15/2001 4:30		25.0			
PropyleneGlycol (mg/L)	3/15/2001 6:30		25.0			
PropyleneGlycol (mg/L)	3/15/2001 8:30		25.0			
PropyleneGlycol_hach (mg/L)	1/9/2001 13:21		150			
PropyleneGlycol_hach (mg/L)	1/9/2001 15:35		150			
PropyleneGlycol_hach (mg/L)	1/10/2001 8:05		65.0			
PropyleneGlycol_hach (mg/L)	1/18/2001 13:47		125			
PropyleneGlycol_hach (mg/L)	1/19/2001 8:30	15.0	65.0			
PropyleneGlycol_hach (mg/L)	1/19/2001 13:30	15.0	65.0			15.0
PropyleneGlycol_hach (mg/L)	1/24/2001 7:48	15.0	125			
PropyleneGlycol_hach (mg/L)	1/31/2001 8:27	15.0	15.0			
PropyleneGlycol_hach (mg/L)	2/2/2001 8:30	15.0	15.0			
Pyrene (ug/L)	11/6/2000 10:35		2.5			
sec-Butylbenzene (ug/L)	11/6/2000 10:35		0.30			
Selenium (mg/L)	11/6/2000 10:35		0.025			
Silver (mg/L)	11/6/2000 10:35		0.003			
StYrene (ug/L)	11/6/2000 10:35		0.35			
Temp (C)	1/27/2000 9:16		36.0			
Temp (C)	2/28/2000 11:05		42.0			
Temp (C)	3/22/2000 9:35		42.0			
Temp (C)	4/27/2000 8:58		42.5			
Temp (C)	5/18/2000 8:45		52.0			
Temp (C)	6/6/2000 10:30		57.0			
Temp (C)	7/25/2000 8:40		56.0			
Temp (C)	8/24/2000 8:25		58.0			
Temp (C)	9/26/2000 9:50		50.0			
Temp (C)	10/31/2000 8:35		45.0			
Temp (C)	11/27/2000 9:02		44.0			
Temp (C)	2/27/2003			1.00	1.00	
Temp (C)	3/20/2003			3.0	1.00	
tert-Butylbenzene (ug/L)	11/6/2000 10:35		0.40			
Tetrachloroethylene (ug/L)	11/6/2000 10:35		0.20			
Thallium (mg/L)	11/6/2000 10:35		0.025			
TKN (mg/L)	1/27/2000 9:16		0.12			
TKN (mg/L)	1/17/2001		0.50			
TKN (mg/L)	1/18/2001		0.50			
TKN (mg/L)	1/19/2001		0.50			
TOC (mg/L)	1/5/2001		110			
TOC (mg/L)	1/8/2001		350			
TOC (mg/L)	1/9/2001		3860			
TOC (mg/L)	1/17/2001		459			
TOC (mg/L)	1/18/2001		130			
TOC (mg/L)	1/19/2001		81.1			
TOC (mg/L)	1/31/2001		14.6			
TOC (mg/L)	2/2/2001		0.50			
TOC (mg/L)	3/13/2001 10:30		4214			
TOC (mg/L)	3/13/2001 12:30		7517			
TOC (mg/L)	3/13/2001 14:30		5441			
TOC (mg/L)	3/13/2001 16:30		4057			
TOC (mg/L)	3/13/2001 18:30		2026			
TOC (mg/L)	3/13/2001 20:30		1472			
TOC (mg/L)	3/13/2001 22:30		2072			
TOC (mg/L)	3/14/2001 0:30		2689			
TOC (mg/L)	3/14/2001 2:30		2366			
TOC (mg/L)	3/14/2001 4:30		1849			
TOC (mg/L)	3/14/2001 6:30		1078			
TOC (mg/L)	3/14/2001 8:30		911			
TOC (mg/L)	3/14/2001 10:30		565			

APPENDIX E

Detailed Laboratory Results and Analytical Data for the SSF CTW Technology Demonstration Project at the Westover Air Force Reserve Base, Chicopee, MA

		Station				
Parameter (Units)	**Date**	**OWin**	**Outfall001**	**Win**	**Wout**	**CB**
TOC (mg/L)	3/14/2001 12:30		84.4			
TOC (mg/L)	3/14/2001 14:30		50.3			
TOC (mg/L)	3/14/2001 16:30		57.7			
TOC (mg/L)	3/14/2001 18:30		43.9			
TOC (mg/L)	3/14/2001 20:30		39.8			
TOC (mg/L)	3/14/2001 22:30		37.2			
TOC (mg/L)	3/15/2001 0:30		36.4			
TOC (mg/L)	3/15/2001 2:30		38.2			
TOC (mg/L)	3/15/2001 4:30		36.4			
TOC (mg/L)	3/15/2001 6:30		40.0			
TOC (mg/L)	3/15/2001 8:30		49.1			
Toluene (ug/L)	11/6/2000 10:35		0.35			
Toluene (µg/L)	11/6/2000 10:35		0.95			
TP (mg/L)	1/17/2001		1.00			
TP (mg/L)	1/18/2001		0.58			
TP (mg/L)	1/19/2001		0.49			
trans-1,2-Dichloroethylene (ug/L)	11/6/2000 10:35		0.40			
trans-1,3-Dichloropropene (ug/L)	11/6/2000 10:35		0.20			
trans-1,4-Dichloro-2-Butene (ug/L)	11/6/2000 10:35		1.1			
Trichloroethylene (ug/L)	11/6/2000 10:35		0.50			
Trichlorofluoromethane (ug/L)	11/6/2000 10:35		0.35			
TSS (mg/L)	1/27/2000 9:16		0.25			
Turbidity (NTU)	1/5/2001		0.77			
Turbidity (NTU)	1/8/2001		0.45			
Turbidity (NTU)	1/9/2001		4.9			
Vinyl Acetate (ug/L)	11/6/2000 10:35		8.2			
Vinyl Chloride (ug/L)	11/6/2000 10:35		0.15			
Zinc (mg/L)	11/6/2000 10:35		0.008			

Note: Values reported as below the detection limit are reported at half the detection limit